01 SOLID FUELS

Sources, winning, properties

14/03026 An intelligent approach to predict pillar sizing in designing room and pillar coal mines

Ghasemi, E. *et al. International Journal of Rock Mechanics and Mining Sciences*, 2014, 65, 86–95.

Various empirical procedures have been developed to determine pillar sizing based on back analysis of failed and successful case histories and statistical analysis techniques. Artificial intelligence techniques are now being used as an alternate to statistical techniques. In this study, the fuzzy logic was applied to predict safe pillar sizing in room and pillar coal mines. The model predicts pillar length and width using depth of cover, mining height, panel width, roof strength rating and loading conditions. The predictive fuzzy model was implemented on fuzzy logic toolbox of MATLAB using the Mamdani algorithm and was developed based on a database including 399 datasets from US room and pillar coal mines. Eighty datasets of this database were used to assess the performance of this fuzzy model. The coefficient of determination (R^2), the variance account for (VAF) and the root mean square error (RMSE) were calculated to check the prediction performance of the model. The R^2, VAF and RMSE values were obtained as 89.3%, 89.27 and 1.39 for the pillar width, and 86.6%, 86.4 and 2.77 for the pillar length. These indices revealed that the developed model is suitable for practical use at mines. In addition, the strength of the relationship between the pillar sizing and the five input parameters were evaluated by the cosine amplitude method and the results showed that the most effective parameter on pillar sizing is loading conditions.

14/03027 Analysis of high molecular compounds in pyrolysis liquids from a german brown coal by FT-ICR-MS

Rathsack, P. *et al. Fuel*, 2014, 115, 461–468.

Pyrolysis liquids from the slow pyrolysis of a German brown coal obtained at different pyrolysis temperatures were analysed by electrospray ionization (ESI) Fourier transform ion cyclotron resonance mass spectrometry in negative ion mode. Singly charged ions in the range from $m/z = 200$ to 700 were observed. Assignment of molecular formulas revealed mainly oxygen containing species, which are most probably acidic compounds ionized during ESI in negative ion mode. Compounds detected were of type O_o, O_oS_1, O_oS_2 and O_oN_1 with oxygen numbers $o = 1, \ldots, 12$ depending on the specific class. The formation or decomposition of certain compound classes upon temperature changes was investigated. It could be shown that summation of observed compound class frequencies in terms of number or intensities is not suitable to identify trends. Identification of temperature dependent behaviour of certain compound classes can only be revealed by looking at individual ions, which is exemplified for carboxylic acids.

14/03028 Caking and coking properties of the thermal dissolution soluble fraction of a fat coal

Shui, H. *et al. Fuel Processing Technology*, 2014, 118, 64–68.

In the coal blending for coke-making, fat coal has a very important role for the caking and coking properties of the coal blends. In this study, a fat coal was thermally dissolved, and the caking and coking properties of the thermal dissolution soluble factions (TDSFs) from different solvents and temperatures were characterized. It was found that the caking properties of TDSFs were better than that of fat raw coal. The TDSFs obtained from non-polar solvents have a higher caking property than those obtained from polar solvents at the same thermal dissolution (TD) temperature. During TD process, polar solvents can thermally dissolve more polyaromatic compounds into TDSF, thus increasing the softening temperature and decreasing the caking property of the TDSF. For the same TD solvent, the TDSFs obtained from higher temperatures have a lower caking property compared to those obtained from lower temperatures because of more aromatic components and oxygen functional groups entering them. Crucible coking determinations were carried out to evaluate the coking property of the TDSFs. The result suggests that when 5% of TDSF and 5% of non-caking sub-bituminous coal were used instead of the same amount of fat coal and gas coal, respectively in the coal blends, the quality of the coke obtained could get to the level of the coke obtained from the standard coal blends (i.e. without TDSF and sub-bituminous coal). Therefore, the use of TDSF in coal blending for coke-making is one of the effective methods for opening the coking coal resources.

14/03029 Characterization of Zhundong subbituminous coal by time-of-flight mass spectrometry equipped with atmospheric pressure photoionization ion source

Zheng, A.-L. *et al. Fuel Processing Technology*, 2014, 117, 60–65.

Zhundong subbituminous coal pretreated with aqueous H_2O_2 was oxidized by aqueous NaOCl and sequentially extracted with diethyl ether (DEE) and ethyl acetate (EA) to afford DEE- and EA-extractable fractions and residue. Both extracts were esterified with CH_2N_2 and analysed using high-performance liquid chromatography/mass spectrometry equipped with electrospray ionization (ESI) or atmospheric pressure photoionization (APPI) ion source. Molecular mass of 60% compounds in the esterified extracts ranged between 200 and 600 Da and more than 20% of the esterified extracts had molecular mass over 600 Da. Toluene and toluene/anisole (vol./vol. = 95/5) were used as dopants for APPI. Low- and non-polar compounds in the esterified extracts were analysed using APPI/MS. Compared to toluene/anisole mixture, toluene greatly increased ionization efficiency of APPI. More molecular associations were detected by ESI than by APPI. Heteroatoms were identified in most of the associated species.

14/03030 Fine structure of Raman spectra in coals of different rank

Ulyanova, E. V. *et al. International Journal of Coal Geology*, 2014, 121, 37–43.

Fine structure of *G* and *D* bands in Raman spectra of various coals is studied. It is shown that the spectra of all subbituminous and bituminous coals can be decomposed into five subcomponents while the spectra of anthracites are best fitted using two, three or four subcomponents depending on coal rank. The analysis enabled to separate one subcomponent of D band, probably responsible for imperfections in graphitic clusters, which shows nearly linear shift in the whole metamorphism range and can play role of the coal type indicator. The authors have found that Raman spectra of the same fat coal reveal one more subcomponent just before underground outburst and only two subcomponents after the outburst. This subcomponent near 1190 cm^{-1} is assignable to oscillations of methyl group bonds and probably can serve as the outburst indicator.

14/03031 Geochemistry and nano-mineralogy of two medium-sulfur northeast Indian coals

Saikia, B. K. *et al. International Journal of Coal Geology*, 2014, 121, 26–34.

The petrology, mineralogy and inorganic geochemistry of two contrasting high-sulfur, vitrinite-rich subbituminous to bituminous coals from the north-eastern region of India have been studied using a combination of optical microscopy, quantitative X-ray diffraction, field-emission scanning electron microscopy, high-resolution transmission electron microscopy and chemical analysis techniques. The study reveals that the Fe nano-particles are present in Indian high-sulfur Tertiary coals including nano-pyrite, Fe-oxyhydroxides and a small amount of sphalerite. The pyrite is present as framboids and unsymmetrical cubic crystals (rhombohedral). They contain potentially hazardous elements, namely As, Pb, and Se measured by energy dispersive spectroscopy. Mineral-matter residues isolated from the coals by low-temperature oxygen-plasma ashing are dominated by carbonate minerals (calcite, dolomite, ankerite), pyrite and pyrite oxidation products (jarosite and coquimbite), kaolinite, illite, and quartz. Sulfate-bearing phases such as tschermigite, bassanite and gypsum are also present, probably as artifacts of the plasma-ashing process.

14/03032 Ignition behavior of single coal particle in a fluidized bed under O_2/CO_2 and O_2/N_2 atmospheres: a combination of visual image and particle temperature

Bu, C. *et al. Applied Energy*, 2014, 115, 301–308.

Single coal particle ignition behaviour was studied in a two-dimensional (200 mm × 20 mm × 400 mm) fluidized bed under O_2/N_2 and O_2/CO_2 atmosphere with O_2 volume concentration in the range of 0–40%, by a combination of visual observation of the volatile flame and measurement of the particle centre temperature. A piece of transparent quartz glass was used as the front wall of the fluidized bed to allow visual observation. The investigated fuel particles were spherical subbituminous coal particles with diameter in a range of 6–13 mm, which were artificially carved from selected original coal particles. The volatile combustion flame was recorded by a colour video camera to analyse its ignition time delay and extinction behaviour. The temperature in the particle centre was measured by a very thin thermocouple to follow the particle heating process. Results indicate that under O_2/CO_2 atmosphere the ignition delay time is much longer than in O_2/N_2 atmosphere. The devolatilization process is controlled by internal and external heat transfer but it is almost unaffected by atmosphere at the same O_2 concentration. The effect of volatile combustion on heating and extinction delay time can be neglected for larger coal particles.

14/03033 Influence from fuel type on the performance of an air-blown cyclone gasifier

Risberg, M. *et al. Fuel*, 2014, 116, 751–759.

Entrained flow gasification of biomass using the cyclone principle has been proposed in combination with a gas engine as a method for combined heat and power production in small to medium scale (<20 MW). This type of gasifier also has the potential to operate using ash-rich fuels since the reactor temperature is lower than the ash melting temperature and the ash can be separated after being collected at the bottom of the cyclone. The purpose of this work was to assess the fuel flexibility of cyclone gasification by performing tests with five different types of fuels: torrefied spruce, peat, rice husk, bark and wood. All of the fuels were dried to below 15% moisture content and milled to a powder with a maximum particle size of around 1 mm. The experiments were carried out in a 500 kW_{th} pilot gasifier with a three-step gas cleaning process consisting of a multi-cyclone for removal of coarse particles, a bio-scrubber for tar removal and a wet electrostatic precipitator for removal of fine particles and droplets from the oil scrubber (aerosols). The lower heating value (LHV) of the clean producer gas was 4.09, 4.54, 4.84 and 4.57 MJ/N m^3 for peat, rice husk, bark and wood, respectively, at a fuel load of 400 kW and an equivalence ratio of 0.27. Torrefied fuel was gasified at an equivalence ratio of 0.2 which resulted in a LHV of 5.75 MJ/N m^3 which can be compared to 5.50 MJ/N m^3 for wood powder that was gasified at the same equivalence ratio. A particle sampling system was designed in order to collect ultrafine particles upstream and downstream the gasifier cleaning device. The results revealed that the gas cleaning successfully removed >99.9% of the particulate matter smaller than 1 μm.

14/03034 Modeling gas-adsorption-induced swelling and permeability changes in coals

Chareonsuppanimit, P. *et al. International Journal of Coal Geology*, 2014, 121, 98–109.

The swelling of a coal matrix as the result of gas adsorption can have important implications in operations related to the production of coalbed gases and the sequestration of greenhouse gases in coalbeds. In view of this, the authors undertook a modelling study to describe the relationships among gas adsorption on coals, coal swelling and permeability changes. Specifically, they incorporated the simplified-local-density (SLD) adsorption model within the theory-based swelling model by Pan and Connell (PC). The resultant, internally consistent SLD-PC model was used to investigate the swelling behaviour caused by adsorption of methane, nitrogen and CO_2 on several coals, using data from the literature. The SLD-PC model was found capable of representing both the gas adsorption and the adsorption-induced swelling data on these coals. The PC swelling model relates the linear strain or adsorption-induced swelling in coals to the surface potential of the coal, which here is calculated by the SLD adsorption model. Two model parameterization scenarios were considered for describing the quantitative relationship between swelling and adsorption surface potential. Results indicate that the SLD-PC approach provides lower errors in representing swelling behaviour than the original PC model utilizing the Langmuir adsorption model. This improvement in representing swelling behaviour with the SLD-PC model, which was especially true for CO_2, is attributed to a combination of two factors: (1) a more accurate description of surface potential and (2) the non-linear relation between the surface potential and strain that is accounted for in the SLD-PC approach. In cases where swelling data were reported without the corresponding gas adsorption data, the authors utilized their previously developed generalized model to predict gas adsorption on coals. The predicted adsorption data were then used successfully in the SLD-PC model for systems lacking experimental adsorption data. The efficacy of this approach was verified using an additional test system from the literature. Further, the hypothesis by Pan and Connell was also tested that coal swelling is more dependent on the molar amount of gas adsorbed than on the particular gas being adsorbed. Current results confirm that the linear strains induced in coals are similar when compared at equal levels of adsorption of different gases. Lastly, the authors utilized adsorption-induced strain information obtained from the SLD-PC approach to model normalized permeability changes in coal. The results suggest that the SLD-PC approach combined with the Pan and Connell permeability model may be capable of providing useful description of the adsorption-induced normalized permeability changes in coal. The development of completely predictive models for coal swelling and permeability changes, however, will require additional experimental data and further testing.

14/03035 Molecular simulation and experimental characterization of the nanoporous structures of coal and gas shale

Firouzi, M. *et al. International Journal of Coal Geology*, 2014, 121, 123–128.

Characterization of coal and shale is required to obtain pore size distribution (PSD) in order to create realistic models to design efficient strategies for carbon capture and sequestration at full scale. Proton nuclear magnetic resonance (NMR) cryoporometry and low-pressure gas adsorption isothermal experiments, conducted with N_2 at 77 K over a P/P_0 range of 10^{-7} to 0.995, were carried out to determine the PSD and total pore volumes to provide insight into the development of realistic simulation models for the organic matter comprising coal and gas shale rock. The PSDs determined on the reference materials (SiliaFlash F60 and Vycor 7930) show a reasonable agreement between low-pressure gas adsorption and NMR cryoporometry showing complementarity of the two independent techniques. The PSDs of coal and shale samples were determined with low-pressure gas adsorption isothermal experiments, but were unable to be measured by NMR cryoporometry. This is likely due to a combined size and pore surface chemistry effect that prevents the water from condensing in the pores, such that when the sample is heated there is no distinction based upon melting or phase change. Molecular modelling is carried out to create the pore structure network in which the transport and adsorption predictions are based. The three-dimensional (3D) pore network, representative of porous carbon-based materials, has been generated atomistically using the Voronoi tessellation method. A comparison of the computed PSD using this method was made to the measured PSD using isothermal low-pressure gas adsorption isothermal experiments on coal and gas shale samples. Applications of this work will lead to the development of more realistic 3D models from which enhanced understanding of gas adsorption and transport for enhanced methane recovery and CO_2 storage applications can be developed.

14/03036 Origin of minerals and elements in the Late Permian coals, tonsteins, and host rocks of the Xinde Mine, Xuanwei, eastern Yunnan, China

Dai, S. *et al. International Journal of Coal Geology*, 2014, 121, 53–78.

This paper reports the mineralogical and geochemical compositions of the Late Permian C2 and C3 coals (both medium-volatile bituminous coal) from the Xinde Mine, near Xuanwei in eastern Yunnan, which is located close to the area with the highest female lung cancer mortality in China. The two coals are characterized by high ash yields and low sulfur contents. Three factors, including sediment-source region, multi-stage volcanic ash generation, and multi-stage hydrothermal fluid injections, were responsible for variations in the geochemical and mineralogical compositions of the Xinde coals. Trace elements, including V, Sc, Co, Ni, Cu, Zn, Se, Zr, Nb, Hf and Ta, are enriched in the coals and were mainly derived from the sediment-source Kangdian Upland region. Major minerals in the samples of coal, roof, floor and non-coal sediment partings include quartz, kaolinite, and chamosite, as well as interstratified illite/smectite and anatase. Chamosite in the coal was derived from reactions between kaolinite and Fe–Mg-rich hydrothermal fluids. However, chamosite in the roof strata was directly precipitated from Fe–Mg-rich hydrothermal fluids or was derived from the alteration of precursor minerals (e.g. biotite) by hydrothermal fluids. Quartz in some samples is very high, especially in the roof strata of the C2 and C3 coal. Such high quartz, along with minor minerals including pyrite, chalcopyrite, sphalerite, calcite, celestite, vanadinite, barite, clausthalite and silicorhabdophane, were derived from multi-stage hydrothermal fluids. The floors of both the C2 and C3 coal seams are fully-argillized fine-grained tuffaceous claystone and the immediate roof of the C2 coal is argillized coarse-grained tuff. The original materials of the floors and roofs of these coal seams were high-Ti alkali basaltic volcanic ashes, as indicated by high TiO_2, Nb, and siderophile elements, and the distribution patterns of rare earth elements. Two intra-seam tonstein layers in the C3 coal were identified based on their lateral persistence, mineralogical mode of occurrence and composition, as well as their elemental composition. The tonsteins are dominated by kaolinite, with minor quartz and possibly mixed-layer illite/smectite. Both tonsteins were derived from dacitic magma. The ratios of Nb/Ta, Zr/Hf and U/Th are much lower in tonsteins than in the adjacent coal benches, which is attributed to the hydrothermal leaching.

14/03037 Palynofacies changes and their reflection on preservation of peat accumulation stages in the Late Permian coal measures of the Bowen Basin, Australia: a new system for coal palynofacies characterisation

Van de Wetering, N. *et al. International Journal of Coal Geology*, 2013, 120, 57–70.

A high-resolution study ($n = 66$) was conducted on Late Permian coal measures of the Bowen Basin, Australia, to observe palynofacies changes during peat accumulation over time. Palynofacies were determined using polytopic vector analysis to derive end members with variable compositions that reflected fine scale environmental changes, within and between seams, of the Kaloola Member. Palynofacies reflect a three-stage succession within the palaeo-peat-forming environments from stable, anoxic conditions at the base,

progressing to variable, oxic conditions toward the top of each seam. In cases where a seam was capped by tuff, rather than siliciclastic sediment, anoxic conditions similar to the bottom of each seam occurred. The results corroborate previous interpretations of palaeofloral communities and provide a new palynofacies model that integrates environmental progression within the coal seams in the Late Permian coal measures of the Bowen Basin. A complementary study of palynological assemblages recognized a shift from *Dulhuntyspora* sp. to *Protohaploxypinus* sp. in the lower Kaloola Member, indicating a change in pollen/spore source. Associations between dispersed palynomorphs and coal phyterals of parent flora remain tenuous beyond class rank, due to poor preservation and taxonomic bias inherent within the sample space. This is the first such palynofacies study to be conducted in the Bowen–Sydney–Gunnedah basin complex, thus opening the way for future work examining regional changes in palynofacies, expressed in both coal and siliciclastic sediments.

14/03038 Rank-dependent formation enthalpy of coal

Sciazko, M. *Fuel*, 2013, 114, 2–9.

In the study reported in this paper, the enthalpy of formation of a complex chemical compound, such as coal, was defined as the difference between the experimentally determined heat of combustion and the thermodynamically calculated heat of combustion of the elementary reactants. The boundary conditions for the approach were defined by the enthalpy of formation of graphite; thus, the aforementioned method should produce a value of zero for graphite. Using the developed correlation for the enthalpy of formation, a model of coal classification was developed based on this thermodynamic quantity, which reflects the structure and technological suitability of coal. According to the analysis of the enthalpy of formation with respect to the composition of coal, the enthalpy of formation may have negative or positive values, depending on the type of fuel. Furthermore, changes in the formation enthalpy are continuous but correspond to different chemical structures. The following values for the enthalpy of formation were obtained: anthracite = +250 kJ/kg, peat < −3200 kJ/kg and medium volatile bituminous coal approximately zero.

14/03039 Structural characteristics of coal functional groups using quantum chemistry for quantification of infrared spectra

Xin, H.-h. *et al. Fuel Processing Technology*, 2014, 118, 287–295.

The distribution and structural characteristics of functional groups from coal infrared spectra is inaccurate. The extinction coefficient differs for different functional groups making the quantitative analysis of their infrared spectra problematic. Although the coefficients of some functional groups have been researched previously, they are inaccurate because of deviations in techniques used and linear fitting. In this study, quantum chemistry methods are used for the quantification of coal infrared spectra based on the Beer–Lambert law. The effect of the extinction coefficients of different functional groups is eliminated. The experimental infrared intensities, unit absorption intensities and their ratios are obtained to calculate the percentage composition of coal functional groups and molecular structure parameters. Accurate distribution and structural characteristics of coal functional groups are obtained. A linear relationship between the distribution of some functional groups and structural parameters is obtained. Multiple structural parameters are used to determine the grade and maturity of coal samples. The ethylene in coal oxidation experiments below 200 °C is consistent with the hydrocarbon-generating potential parameters. These results will improve the accuracy of the quantitative analysis of infrared spectra for determining coal structural features and provide an index for the utilization and prevention of the spontaneous combustion of coal.

14/03040 The fate of sulfur in coal during carbonization and its effect on coal fluidity

Mochizuki, Y. *et al. International Journal of Coal Geology*, 2013, 120, 50–56.

The fate of sulfur during carbonization at 3 °C/min of seven caking coals with carbon and sulfur contents of 80–88 and 0.55–1.8 mass%-daf, respectively, has been studied using a flow-type fixed-bed quartz reactor to examine its effect on coal fluidity in caking coal. Organic sulfur transfers to H_2S or tar-S from 200 to 350 °C, and FeS_2 decomposes to H_2S and FeS above 350 °C. The H_2S formation rate exhibits two distinct peaks at 450 and 550 °C. The amounts of H_2S that evolved and organic sulfur that remained in cokes often depend on carbon contents in raw coals. The maximum fluidity (MF), determined by the Gieseler plastometer method, appears at around 450 °C for all of the coals examined, and the values range from 1.1 to 4.1 log(ddpm). The MF value tends to decrease with increasing amounts of FeS_2 or organic sulfur remaining in solid products up to 450 °C. Sulfur-containing compounds, such as elemental sulfur, FeS_2, diphenyl disulfide and dibenzothiophene, added to caking coal adversely affect coal fluidity.

14/03041 Variation with time of cell voltage for coal slurry electrolysis in sulfuric acid

Gong, X. *et al. Energy*, 2014, 65, 233–239.

To explain the time dependence of cell voltage in coal water slurry (CWS) electrolysis, the effects of three coal types along with graphite, CWS concentration and catalysts on cell voltage are examined. Results show that the overall cell voltage for CWS electrolysis is lowered as coal rank decreases. The four overall types carbonaceous material show successive reductions in $U^{\theta} + \eta$ for CWS electrolysis which are greater than those of iR, where U^{θ} is the theoretical reversible potential for water electrolysis, and η is the sum of the anodic and cathodic overpotentials. The cell voltage for demineralized lignite water slurry (DLWS) electrolysis is lowered by addition of Fe^{2+} or Fe^{3+} ions, the former being more effective. The cell voltage for demineralized bituminous water slurry electrolysis decreases with the addition of transition metal ions in the order $Fe^{2+} < Ni^{2+} < Co^{2+}$. Additionally, it is found that the DLWS electrolysis cell voltage is lowered with increasing DLWS concentration. Results suggest that cell voltage reduction may be attributed to the decrease in $U^{\theta} + \eta$ for CWS electrolysis.

Preparation

14/03042 A study on the effects of catalysts on pyrolysis and combustion characteristics of Turkish lignite in oxy-fuel conditions

Abbasi-Atibeh, E. and Yozgatligil, A. *Fuel*, 2014, 115, 841–849.

The catalytic pyrolysis and combustion characteristics of low calorific value Turkish lignite in various ambient conditions were explored and the evolution of gases during pyrolysis tests was examined using a thermogravimetric analyser coupled with a Fourier transform infrared spectrometer (FTIR). Potassium carbonate (K_2CO_3), calcium hydroxide ($Ca(OH)_2$) and iron(III) oxide (Fe_2O_3) were employed as precursors of the catalysts and compared to the raw-form (no catalyst added) to investigate the effects of potassium, calcium and iron on pyrolysis and combustion. Pyrolysis tests were carried out in 100% N_2 and 100% CO_2 ambient conditions which are the main diluting gases in air and oxy-fuel combustion. These experiments revealed that the major difference between pyrolysis in these two ambient conditions was observed above 720 °C and derivative thermogravimetric profiles experienced sharp peaks at 785 °C in 100% CO_2 which can be attributed to a char-CO_2 gasification reaction. Furthermore, K_2CO_3 was found to be the most effective catalyst in the char gasification reaction during pyrolysis tests in 100% CO_2. Combustion experiments were carried out in various oxygen concentrations from 21% to 35% O_2 in N_2 and CO_2 ambient conditions. Combustion tests carried out in O_2/CO_2 ambient conditions revealed that for 30% and 35% O_2, the relative active sequence of catalysts to the reaction rates of devolatilization can be described as Fe ≫ K > Ca > Raw-form, and Fe > Ca > raw-form ≫ K respectively. Furthermore, potassium catalyst had the best char reactivity due to its much higher reaction rates for all oxygen concentrations. The burnout temperature (T_b) also experienced a significant drop in the case of the K-based catalyst. Finally, emission profiles of the evolved gases, CO_2, CO, H_2O, SO_x and COS, were analysed during pyrolysis tests in both N_2 and CO_2 ambient conditions using the FTIR method.

14/03043 Comparison of desulfurization characteristics of lignite char-supported Fe and Fe–Mo sorbents for hot gas cleaning

Yin, F. *et al. Fuel Processing Technology*, 2014, 117, 17–22.

The desulfurization behaviour of novel Fe and Fe–Mo sorbents supported using Chinese lignite chars for desulfurization of hot coal gases was investigated and compared. The desulfurization experiments were carried out using a fixed-bed quartz reactor over a temperature range of 673–873 K in simulated coal gas containing 0.47% H_2S and 0.047% COS. The product gases composition and chemical phases of sorbents were analysed using a gas chromatograph and X-ray diffractometer, respectively. The results show that Fe and Fe–Mo sorbents supported on lignite char demonstrated high desulfurization efficiency under the present experimental conditions. The sulfur capacity of Fe-based sorbents is determined by the amount of iron contained in the sorbents and the addition of Mo into the Fe-based sorbents effectively improves the desulfurization efficiency of char-supported Fe sorbents.

14/03044 CO_2 gasification of coal under concentrated thermal radiation: a numerical study

Kenarsari, S. D. and Zheng, Y. *Fuel Processing Technology*, 2014, 118, 218–227.

Solar coal gasification is a promising technology to convert coal into gaseous fuel. In this study, a steady-state one-dimensional two-phase model was developed to simulate CO_2 gasification of coal in a quartz

fluidized bed reactor directly exposed to concentrated thermal radiation as the heating source. Coupled with chemical kinetics, the present model encompasses energy equations for the gas phase, the solid phase, and the quartz reactor. The discretized energy equations were solved using the Levenberg–Marquardt algorithm. The initial carbon particle size was 140 μm and the peak radiative heating flux was as high as 1270 kW m^{-2}. The CO_2 flow velocity for fluidization was in the range of 0.10 to 4.0 m min^{-1} under standard conditions (25 °C, 1 bar). Simulated gas and coal particle temperature distributions, CO production rates, product gas compositions, and coal conversion rates were in good agreement with the experimental data reported in the literature. Furthermore, the present simulation provided insightful explanation on the optimum fluidization velocity for maximum CO production rate or maximum solar to chemical energy conversion. The present simulation also provided an energy balance analysis of the solar CO_2 gasification process, which is challenging to conduct in experimental studies.

14/03045 Kinetic and thermodynamic studies on the mechanism of low-temperature oxidation of coal: a case study of Shendong coal (China)

Zhang, Y. *et al*. *International Journal of Coal Geology*, 2013, 120, 41–49.

Due to the heterogeneous characteristics of coal constituents, it is difficult to directly apply conventional methods for calculating the kinetic and thermodynamic characteristics of coal oxidation at low temperatures. In this work, the complex macromolecular matrix of coal was divided into elements C, H, O, S and N, which are all involved in oxidation reactions. Based on the changes in element occurrence during low-temperature oxidation of coal, the kinetic and thermodynamic characteristics of coal oxidation were studied at temperatures below 200 °C. A kinetic study revealed that the changes in element occurrence during coal oxidation at low temperature followed pseudo-first-order kinetics. The activation energies for the changes in element occurrence obtained by using the pseudo-first order kinetic have been found to be very close to those calculated by applying the Coats and Redfern's equation. At a particular temperature, the release of element H showed the highest rate constant (K) and lowest activation energy (E_a) compared with those same values for C and N. A kinetic compensation effect between K and E_a was also observed for the changes in element occurrence. Negative enthalpy (ΔH) values indicated that the changes in S and O occurrence produced heat, while the changes in C, H, and N occurrence were endothermic, having positive ΔH values. The low values of the rate constants and frequency factors suggested the non-spontaneous nature of changes in element occurrence, which was further supported by the negative entropy (ΔS) values and positive Gibb's free energy (ΔG) values associated with the changes in element occurrence. The enthalpies of formation for CO_2, CO, and H_2O were calculated, and the exothermic nature for the formation of CO_2 and H_2O was evident given their negative ΔH values. Based on the kinetic and thermodynamic characteristics of low-temperature coal oxidation, the mechanism of coal self-heating was also explored.

14/03046 Simulation of hydraulic fracturing using particle flow method and application in a coal mine

Wang, T. *et al*. *International Journal of Coal Geology*, 2014, 121, 1–13.

The purpose of hydraulic fracturing is to improve the gas permeability of a coal seam by the high-pressure injection of fracturing fluid into cracks. This paper simulates the hydraulic fracturing of a coal seam, investigates relevant parameters and analyses the connection between macroscopic mechanical parameters and mesoscopic mechanical parameters based on two-dimensional particle flow code (PFC^{2D}). Furthermore, the influence of macroscopic mechanical properties on the initiation and size of cracks is studied based on various combinations of particle flow calculations. Empirical formulae for the breakdown pressure and fracture radius are derived. Moreover, the effect of the injection parameters on crack propagation is computed and analysed, after which the relevant empirical formula is proposed. Finally, numerical simulation of the working face N3704 at Yuyang coal mine is conducted, and the comparison of results from simulation, empirical formulae and field observation is investigated. The research findings of this paper may provide a reference for selecting injection parameters and forecasting the effect in practical hydraulic fracturing applications.

14/03047 Thermal annealing of coal at high temperature and high pressure. Effects on fragmentation and on rate of combustion, gasification and oxy-combustion

Senneca, O. and Cortese, L. *Fuel*, 2014, 116, 221–228.

This paper addresses thermal annealing of coal under the combined effects of temperature and pressure. Coal particles were pyrolysed in a pressurized heated grid reactor with heating rate of 5000 °C/s up to 1600 °C. The pressure during heat treatment was set to values in the range 1–12 bar. After heat treatment, char samples were collected and subjected to the following analyses: (1) isothermal and non-isothermal thermogravimetric analysis, in order to measure their reactivity towards oxygen, carbon dioxide and mixtures of oxygen–carbon dioxide; (2) X-ray diffraction and porosimetric analysis in order to investigate their structure; and (3) laser light scattering particle analysis in order to assess the extent of fragmentation experienced during heat treatment. Results show that on heat treatment coal particles undergo severe thermal annealing and extensive fragmentation. For a given temperature of heat treatment, the effect of pressure of char preparation turns out to be non-monotonous: at 1500 °C both char porosity and reactivity pass through a minimum at pressure in the order of 2–5 bar. The probability of fragmentation and the degree of graphitization follow a specular trend, with a maximum at pressures of 2–5 bar.

14/03048 Underground hydraulic mining of thin sub-layer as protective coal seam in coal mines

Li, D. *International Journal of Rock Mechanics and Mining Sciences*, 2014, 67, 145–154.

Extracting protective coal seams is effective in improving low gas permeability and reducing the danger of coal and gas outbursts. However, extracting protective coal seams requires the existence of appropriate protective layers. Because the exploitation periods of protective layers are long, considerable investments of personnel and material are required. To reduce the cost and time associated with extracting protective layers and to overcome the limitations associated with extracting protective layers, a method for underground hydraulic mining of a thin sub-layer as a protective coal seam has been introduced. The main idea of the method is to extract a thin sub-layer in a fixed horizon as a protective coal seam for other sub-layers using cross drills and hydraulic bits. This method was first tested in the Yian mine to verify its effectiveness, and the stress, the permeability coefficient and the gas drainage volume in the hydraulic mining area were determined. After hydraulic mining, the largest horizontal principal stress and the largest vertical principal stress were greatly reduced in the hydraulic mining area and were increased in the area nearby the hydraulic mining. Before the hydraulic mining of a thin sub-layer as a protective seam, the average permeability coefficient in the hydraulic mining area was 0.00675 m^2/MPa^2 d, and the average volume of gas drainage for a single cross drill was 0.0142 m^3/min. After hydraulic mining, the average permeability coefficient in the hydraulic mining area was 2.703 m^2/MPa^2 d, 400 times greater than before, and the average volume of gas drainage for a single cross drill was 0.586 m^3/min, 41.3 times greater than before. According to the determined data of the relative stress changes and the permeability coefficient, it was found that the permeability increased greatly with the reduction of the principal stress after the hydraulic mining in the trial region. The authors determined several groups of data for the permeability coefficient after the hydraulic mining only; therefore, the change between the permeability coefficient and the relative stress is not discussed in this paper. As the direct floor of the 2_1 coal seam is sandy mudstone, the water that is introduced into the rock mass during hydraulic mining made the direct floor expand, causing the increase of the stress and the decrease of the permeability in the direct floor, this is conducive to the determination of the permeability coefficient. Similarly, the water that is introduced into the bottom of the coal seam during hydraulic mining caused the increase of the stress and the decrease of the permeability in the coal seam. However, considering that the protective layer is very thin and at the bottom of coal seam, the influence of the water on the permeability of coal seam is relatively small. The test results show that this method can effectively relieve the pressure and increase the permeability of the protected sub-layer in less time and at a lower cost than conventional protective layer extraction.

14/03049 Upgrading and dewatering of low rank coals through solvent treatment at around 350 °C and low temperature oxygen reactivity of the treated coals

Fujitsuka, H. *et al*. *Fuel*, 2013, 114, 16–20.

The authors have recently presented a novel method that not only dewaters but upgrades low-rank coals under rather mild conditions. The method treats coal in non-polar solvents, such as 1-methylnaphthalene, at temperatures <350 °C. It was found that the treated coals were almost free from moisture and had heating values corresponding to subbituminous or bituminous coal. One of the important questions remaining to be considered for the method is if this solvent treatment method can suppress the self-ignition tendency of low-rank coals. In this study, low-temperature oxygen reactivities at 65 °C, which may be linked to the self-ignition tendencies, were examined for the samples prepared from an Australian brown coal by the proposed treatment. The oxygen reactivities of the extracted fractions were found to be much smaller than the oxygen reactivity of the raw coal. The oxidation reactivity of the solvent treated coal, the mixture of extracted fractions and residue, was smaller than that of the residue, but it was slightly larger than the oxygen reactivity of the raw coal. On the basis of the low-temperature oxidation data and detailed analyses of the extract and residue, the mechanism of the low-temperature oxidation and the possibility of the proposed solvent treatment as a method to suppress the low temperature oxidation reactivity of low-rank coals were examined.

14/03050 $^{18}O_2$ label mechanism of sulfur generation and characterization in properties over mesoporous Sm-based sorbents for hot coal gas desulfurization

Liu, B. S. *et al. Journal of Hazardous Materials*, 2014, 267, 229–237.
Using a sol–gel method, Sm*Me*O_x/MCM-41 or SBA-15 (*Me* = Fe, Co and Zn) and corresponding unsupported sorbents were prepared. The desulfurization performance of these sorbents was evaluated over a fixed-bed reactor and the effects of reaction temperature, feed and sorbent composition on desulfurization performance were studied. Samarium-based sorbents used to remove H_2S from hot coal gas were reported for the first time. The results of successive sulfidation/regeneration cycles revealed that $SmFeO_3$/SBA-15 sorbent was suitable for desulfurization of hot coal gas in the chemical industry. The formation of elemental sulfur during both sulfidation and regeneration processes depended strongly on the catalytic action of Sm_2O_2S species, which was confirmed for the first time via high sensitive time of flight mass spectrometer (TOF-MS) using 6%vol $^{18}O_2$/Ar regeneration gas and can reduce markedly procedural complexity. The sorbents were characterized using N_2-adsorption, high-resolution transmission electron microscopy, X-ray diffraction, temperature-programmed reduction of H_2, thermogravimetry and time-of-flight mass spectrometry techniques.

Economics, business, marketing, policy

14/03051 Economic analysis of a supercritical coal-fired CHP plant integrated with an absorption carbon capture installation

Bartela, Ł. *et al. Energy*, 2014, 64, 513–523.
Energy investments in Poland are currently focused on supercritical coal-fired unit technology. It is likely that in the future these units will be integrated with carbon capture and storage (CCS) installations to reduce greenhouse gas emissions into the atmosphere. A significant share of the energy market in Poland is made up of coal-fired combined heat and power (CHP) plants. The integration of these units with CCS installations can be economically inefficient. However, the lack of such integration enhances the investment risk due to the possibility of the future high price of emission allowances. This paper presents the results of an economic analysis aimed at comparing three cases of CHP plants, one without an integrated CCS installation and two with such installations. The same steam cycle structure for all variants was adopted. The cases of integrated CHP plants differ from each other in the manner in which they recover heat. For the evaluation of the respective solutions, the break-even price of electricity and avoided emission cost were used. For the competitiveness of integrated plants, the recovered heat within the CCS installation is very important. For the maximization of the economic effectiveness of CHP plants integrated with CCS installations compared with CHP plants without such integration, the maximization of annual operation time is most important. Apart from an increase in the price of greenhouse gases emission allowances, the most important factor for enhancing the competitiveness of CHP plants integrated with CCS installations, as far as the development of the CCS technology is concerned, is decreasing the investment costs and operation and maintenance costs, which are primarily related to carbon dioxide separation, transport and storage process. An important factor that incurs significant costs for CHP plants integrated with CCS installations is the very significant heat consumption required for the desorption process. It seems that when full commercialization of CCS technology is achieved, the heat requirements will be much less than those obtained in the current study. Alternative methods of carbon dioxide separation need to be considered, however there has been encouraging and rapid development in this area. A separation method that is uniquely predisposed for cooperation with CHP plants is the membrane separation method because of the lack of the requirement to supply heat. Because of significant changes in the characteristics of CHP plants integrated with CCS installations, which can be seen in a reduction of the annual production of useful heat, research regarding alternative ways to supply heat for the desorption process are very important. A competitive method for meeting the heat demand may be the use of external sources, such as gas turbine systems.

14/03052 Local community opinions regarding the socio-environmental aspects of lignite surface mining: experiences from central Poland

Badera, J. and Kocoń, P. *Energy Policy*, 2014, 66, 507–516.
Surface lignite mining covers large areas and usually generates social conflicts which pose one of several energy security threats to certain states. Therefore, defining the social conditions determines the success of a mining project. Two communes were chosen for a public opinion study: Kleszczów, where the Belchatów mine is located, and Zloczew, where a lignite deposit will soon be developed. The analysis shows, as opposed to other areas in Poland that have been projected for development, that both local communities are characterized by a high level of acceptance for lignite mining. In both cases, awareness about the profits was stronger than anxiety about the investment's negative effects. However, most inhabitants could not assess the mining company's diligence concerning its responsibility for mining damages as well as the diligence of external experts assessing the environmental impacts of excavation. Most respondents also could not assess if the legal regulations of public participation in the decision process were sufficient, but the negative opinions outweighed the positive ones. From the perspective of the energy policy, dialogue-type social communication is needed for every case of a new energy-mining project. Research on local public opinion should be the first step to opening up a social debate.

14/03053 The false promises of coal exploitation: how mining affects herdsmen well-being in the grassland ecosystems of Inner Mongolia

Dai, G. S. *et al. Energy Policy*, 2014, 67, 146–153.
The grasslands of Inner Mongolia are not only the source of the necessary resources for the survival and development of herdsmen, but also represent a significant green ecological barrier in north China. Coal-mining production is important in maintaining gross domestic product growth in Inner Mongolia. However, over-exploitation has created serious problems, such as pollution of the environment and significant decreases in grassland ecosystem services, in addition to impacting the well-being of herdsmen and other people. Based on questionnaires survey performed among 864 herdsmen addressing the relationship between coal exploitation in grasslands and human well-being in Xilinguole League in Inner Mongolia, it was found that: (1) coal resource exploitation in these grasslands does not benefit the herdsmen by increasing their incomes; (2) the rapid development of this resource has not obviously materially improved the life of the herdsmen; and (3) these activities have increased the risks that herdsman will have to endure in the future. Overall, coal resource exploitation in grasslands has more negative than positive effects on the well-being of herdsmen. The authors propose that the conservation of coal resources and improvement of ecological compensation should be carried out without blindly pursuing economic growth, instead of focusing on economic development and structural adjustments.

14/03054 The magnitude of the impact of a shift from coal to gas under a carbon price

Wagner, L. *et al. Energy Policy*, 2014, 66, 280–291.
This study evaluates the extent of the pass through of increased fuel and carbon costs to wholesale prices with a shift of generation from coal- to gas-fired plants. Modelling of Australia's national electricity market in 2035 is undertaken using Australian energy market operator assumptions for fuel costs, capital costs and demand forecasts. An electricity market simulation package (PLEXOS), which uses deterministic linear programming techniques and transmission and generating plant data, is used to optimize the power system and determine the least-cost dispatch of generating resources to meet a given demand. It was found that wholesale market prices increase due to the full pass through of the increased costs of gas over coal as an input fuel and the carbon price. In addition, it was found that wholesale prices increase by more than the pass through of fuel and carbon costs because of the fact that generators can charge infra-marginal rents and engage in strategic behaviour to maximize their profits.

Derived solid fuels

14/03055 Briquetting of carbon-containing wastes from steelmaking for metallurgical coke production

Diez, M. A. *et al. Fuel*, 2013, 114, 216–223.
This work focuses on the manufacture of briquettes by using carbon-containing wastes from steelmaking as fillers and binders for use in coke ovens to produce metallurgical coke. Coal-tar sludges from the tar decanter of a by-products coking plant were employed individually as a binder or combined with other wastes, such as oils from the steel rolling mills and deposits from the coke oven gas pipelines. Another objective of this study was to use alternative low-cost fillers such as the coal generated after routine cleaning operations in the coal stockyards, so as to reduce the overall cost of briquette manufacture. Carbon briquettes with different formulations produced by a roll-press machine were tested in a semipilot movable wall oven by adding them to a coking blend at a ratio of 10 wt%. The quality of the cokes produced was assessed by measuring of their reactivity towards CO_2 and mechanical resistance before and after gasification with CO_2. In

general, the coke quality parameters did not show any significant deterioration as a result of the addition of carbon briquettes when the amount and the nature of the binder and the particle size of the filler were optimized. Partial briquetting of the charge enabled cokes to be produced according to the specific requirements of blast furnace.

14/03056 Chemical/physical properties of char during devolatilization in inert and reducing conditions

Qian, L. *et al. Fuel Processing Technology*, 2014, 118, 327–334.

The activities of coal chars strongly depend on char chemical/physical properties. In this work, the chars were obtained from rapid pyrolysis of Yuanbaoshan lignite in a drop-tube furnace (DTF) (1473 K, 2×10^4 K/s, in N_2), and in a flat flame flow reactor (FFR) under a reducing atmosphere similar to that in fuel-rich region of full-scale combustion. The chemical structures and physical properties of coal and chars from different extent of devolatilization were examined in order to get a better understanding of char reactivity. ^{13}C-nuclear magnetic resonance spectroscopy was used to measure the chemical structures quantitatively. N_2 adsorption and CO_2 adsorption were applied to characterize the physical properties. Results show that pyrolysis is a process of aliphatic compounds release, with a huge number of micropores formed and macropores declined. The chemical structures of mature char are independent of the pyrolysis conditions. The chemical structures of mature chars from both DTF and FFR are remarkably similar, although the proximate and ultimate analyses of them are different. Mature chars show different physical properties, with FFR mature char mainly having micropores and DTF mature char containing both micropores and mesopores. The different reactivity of fully devolatilized chars formed in different pyrolysis conditions mainly depends on physical properties rather than on chemical structures.

14/03057 Economic, environmental and social assessment of briquette fuel from agricultural residues in China – a study on flat die briquetting using corn stalk

Hu, J. *et al. Energy*, 2014, 64, 557–566.

Biomass can be relatively easily stored and transported compared with other types of renewable energy sources. Crop straw can be converted into densified solid biofuel via briquette fuel technology to expand its possible applications and enhance its utilization efficiency. However, the potential economic, environmental and social impacts of crop straw briquette fuel need to be assessed before its large-scale use. This paper provides a comprehensive evaluation of these impacts for a fully-operating 2×10^4 t/a corn stalk briquette fuel plant in China. The results show that with a life time of 15 years, a purchase price of 150 RMB/t for corn stalk and the current sales price of 400 RMB/t for briquette fuel, the plant has a net present value of 9.6 million RMB or US$1.5 million, an internal rate of return of 36% and a short investment payback period of 4.4 years. The life cycle greenhouse gas emissions are found to be 323 t CO_2,e/year or 1 kg CO_2,e/GJ, much lower than that of coal. Additionally, the process reduces pollution by decreasing the amount of corn stalk that is discarded or burnt directly in the field. In terms of social impacts, the use of corn stalk briquetting fuel plant is expected to play an important role in increasing local residents' income, improving rural ecological environments, alleviating energy shortages, guaranteeing energy security, and promoting new rural reconstruction.

14/03058 Flexural fatigue performance and electrical resistance response of carbon nanotube-based polymer composites at cryogenic temperatures

Wei, Z. *et al. Cryogenics*, 2014, 59, 44–48.

This study considers the flexural failure and electrical resistance change of carbon nanotube (CNT)-based polymer composites under cyclic loading at cryogenic temperatures. Fatigue tests were performed on CNT/polycarbonate composites at room temperature and liquid nitrogen temperature (77 K) using the three-point bending method, and the measurements of the specimen electrical resistance were made during the tests. Also, the specimen fracture surfaces were examined by scanning electron microscopy to verify the failure mechanisms of the nanocomposites. The dependence of the mechanical and electrical responses of the nanocomposites on the temperature and the nanotube content was then discussed.

14/03059 Improved dispersion of carbon nanotubes in aluminum nanocomposites

Simões, S. *et al. Composite Structures*, 2014, 108, 992–1000.

This study investigated the influence of the dispersion technique of carbon nanotubes (CNT) in the production of aluminium matrix nanocomposites. Three production routes using different dispersion techniques were tested: in the R1 route the CNT were dispersed using an ultrasonic bath; in the R2 route the dispersion was achieved by ultrasonication, while in the R3 route the dispersion and mixing were performed by ultrasonication CNT and Al powders. Nanocomposites with several CNT contents (0.25–2.0 wt%) were produced by conventional powder metallurgy procedures. Microstructural characterization by scanning and transmission electron microscopies revealed that the best dispersion of the CNT is obtained using the R3 route. Nanocomposites with 0.75 wt% of CNT exhibit well dispersed and embedded nanotubes and the highest hardness and tensile strength. The observed 200% increase in the tensile strength attested the strengthening effect of the CNT and the efficiency of the new dispersion treatment (the R3 route).

14/03060 Influence of biomass on metallurgical coke quality

Montiano, M. G. *et al. Fuel*, 2014, 116, 175–182.

Two industrial coal blends used in coke making were subjected to tests in order to assess the influence of waste sawdust (SC2 from chestnut and SP1 from pine) on the quality of the coke produced. The biomass was added in quantities of up to 5 wt%. It was observed that biomass produced a substantial decrease in the plastic properties of the industrial coal blend, with reductions in Gieseler maximum fluidity of around 50% for 3 wt% additions of the two different sawdusts. Carbonizations with sawdust additions ranging from 0.75 to 5 wt% were carried out in a movable wall oven of 17 kg capacity. The bulk density of the charge was observed to decrease with increasing amounts of sawdust with negative consequences on the quality of the cokes produced. Mechanical strength was determined by means of the JIS test. Coke reactivity and post-reaction strength were also assessed. The amount of sawdust added was low to prevent any deterioration in coke quality. The advantage of using biomass in coking blends should be seen as a possible way to reduce costs and CO_2 emissions and to incorporate alternative raw materials in coke production.

14/03061 Mechanical, pyrolysis, and combustion characterization of briquetted coal fines with municipal solid waste plastic (MSW) binders

Massaro, M. M. *et al. Fuel*, 2014, 115, 62–69.

Significant ecological concerns and attractive financial opportunities are raised by growing deposits of waste coal fines in the USA. These fines can potentially be utilized by extrusion or roller press briquetting along with a binder to impart mechanical strength and water resistance to the briquettes. This research focuses on low-density polyethylene (LDPE) as a binder, which is abundant in waste streams and possesses desirable energy, waterproofing and binding characteristics. The goal of this study was to characterize a briquetted fuel made from waste coal and LDPE that may be an economic and ecologic viable substitute for conventional stoker coal. Thermal and mechanical analyses of the fuel were conducted using standard techniques including compression and attrition testing, bomb calorimetry, thermogravimetric analysis/differential scanning calorimetry, and laboratory-scale combustion testing. The results of this work indicate that LDPE is an effective binding agent when incorporated at suitable concentrations and particle sizes. Addition of 10% LDPE increases the measured higher heating value of the coal from 21.9 to 24.3 MJ/kg and imparts water resistance to the compacted fuel. Differential scanning calorimetry of coal/LDPE mixtures indicates a significant interaction, consistent with prior research. Addition of LDPE in concentrations as low as 5% eases ignition of the fuel by significantly lowering the onset temperature of exothermic decomposition. Laboratory-scale combustion experimentation confirms that ignition characteristics of the parent coal are positively influenced by the addition of LDPE.

14/03062 Mineralogy and reactivity of cokes in a working blast furnace

Gupta, S. *et al. Fuel Processing Technology*, 2014, 117, 30–37.

Coke samples from the tuyere level of a blast furnace were obtained through tuyere drilling. The mineral matter of tuyere-level cokes was quantified using SIROQUANT and examined using a scanning electron microscope. The apparent CO_2 reaction rates were measured using a fixed bed reactor. About 50% of the total inorganic matter of tuyere cokes was found to occur as amorphous or glassy phase. At most of the tuyere-level locations, quartz and mullite contents of the feed coke decreased significantly or disappeared. Silicon carbide and gupeiite were found to be the most notable and common silicon- and iron-bearing minerals of cokes particularly in the raceway region while gehlenite and spinel were the typical calcium- and magnesium-bearing minerals respectively. Tuyere-level cokes also indicated the presence of significantly high potassium levels as well as the graphite formation. The apparent reaction rate of tuyere-level cokes is shown to increase up to 10 times of the feed coke reaction rate, and is strongly related to the total amount of potassium species. The study highlights the strong influence of the raceway temperature, the alkali loading and the hot metal presence on the modification of the mineralogy and reactivity of tuyere-level cokes with implications on coke selection criterion.

14/03063 Pyrolysis kinetics of coking coal mixed with biomass under non-isothermal and isothermal conditions

Jeong, H. M. *et al. Bioresource Technology*, 2014, 155, 442–445.

To investigate the kinetic characteristics of coking coal mixed with biomass during pyrolysis, thermogravimetric and thermo-balance reactor analyses were conducted under non-isothermal and isothermal condition. Yellow poplar as a biomass (B) was mixed with weak coking coal (WC) and hard coking coal (HC), respectively. The calculated activation energies of WC/B blends were higher than those of HC/B blends under non-isothermal and isothermal conditions. The coal/biomass blends show increased reactivity and decreased activation energy with increasing biomass blend ratio, regardless of the coking properties of the coal. The different char structures of the WC/B and HC/B blends were analysed by Brunauer–Emmett–Teller analysis and scanning electron microscopy.

14/03064 Synergistic effects and kinetics thermal behaviour of petroleum coke/biomass blends during H_2O co-gasification

Edreis, E. M. A. *et al. Energy Conversion and Management*, 2014, 79, 355–366.

This study investigates the possible synergistic interactions between the Sudanese lower sulfur petroleum coke (PC) and sugar cane bagasse (SCB) during H_2O co-gasification with three concentration values (25%, 50% and 75% v/v) using a thermogravimetric analyser at 20 °C/min. The kinetic thermal behaviour, and effects of both H_2O concentration and fuel blending ratio were investigated. The results show that, significant interactions existed in both reaction stages of samples, and become less when PC content and H_2O concentration are 50%. Petroleum coke showed only one char gasification stage at (>700 °C) at 75% H_2O. Some kinetics models, such as the homogeneous and shrinking core models, were studied by the Coats–Redfern method in order to observe the optimum reaction mechanism for the H_2O gasification of samples, describe the best reactive behaviour and determine the kinetic parameters. The results showed that, the co-gasification behaviour and kinetic parameters have a significantly influenced by increasing both H_2O concentration and PC content. The boundary controlled reaction model (R2) shows the lowest values of activation energy (E) for all samples and H_2O concentrations. Finally, all the models are successfully utilized to predict the experimental data under all H_2O concentration values.

14/03065 The effect of char properties on gasification reactivity

Duman, G. *et al. Fuel Processing Technology*, 2014, 118, 75–81.

In this study, CO_2 gasification of raw and acid-washed chars obtained from various types of lignocellulosic biomasses (woody and agricultural waste biomasses) was studied under isothermal conditions (850 °C) using thermogravimetric analysis. The effect of surface area and alkali/earth alkali metals on the reactivity of the chars was investigated. The different kinetic models were used to fit with the reactivity data by using least square method. The gasification of chars with higher surface area was found to be faster than that of chars having lower surface area. The acid treatment decreased the overall gasification rate for each raw chars. However, although the alkali index values of chars obtained from agricultural biomasses had equal or higher than that of woody biomass chars, their initial rates were considerably lower. It was concluded that indigenous alkali metals of chars have a remarkable influence of gasification reactivity but an adequate surface area should be provided to react with CO_2.

14/03066 The influence of feedstock and production temperature on biochar carbon chemistry: a solid-state ^{13}C NMR study

McBeath, A. V. *et al. Biomass and Bioenergy*, 2014, 60, 121–129.

Solid-state ^{13}C nuclear magnetic resonance (NMR) spectroscopy was used to evaluate the carbon chemistry of 26 biochars produced from 11 different feedstocks at production temperatures ranging from 350 to 600 °C. Carbon-13 NMR spectra were acquired using both cross-polarization (CP) and direct polarization (DP) techniques. Overall, the corresponding CP and DP spectra were similar, although aromaticity was slightly higher and observability much higher when DP was used. The relative size and purity of the aromatic ring structures (i.e. aromatic condensation) were also gauged using the ring current technique. Both aromaticity and aromatic condensation increased with increasing production temperature, regardless of the feedstock source. However, there were clear differences in these two measures for biochars produced at the same temperature but from different feedstocks. Based on a relationship previously established in a long-term incubation study between aromatic condensation and the mean residence time (MRT) of biochar, the MRT of the biochars was estimated to range from <260 to >1400 years. This study demonstrates how the combination of feedstock composition and production temperature influences the composition of aromatic domains in biochars, which in turn is likely to be related to their recalcitrance and ultimately their carbon sequestration value.

14/03067 Water uptake in biochars: the roles of porosity and hydrophobicity

Gray, M. *et al. Biomass and Bioenergy*, 2014, 61, 196–205.

This study assessed the effects of porosity and hydrophobicity on water uptake by biochars. Biochars were produced from two feedstocks (hazelnut shells and Douglas fir chips) at three production temperatures (370, 500 and 620 °C). To distinguish the effects of porosity from the effects of hydrophobicity, the uptake of water was compared to the uptake of ethanol (which is completely wetting and not affected by hydrophobic materials). For both feedstocks, low temperature biochars took up less water than high-temperature biochars but the same amount of ethanol, suggesting that differences in water uptake based on production temperature reflect differences in surface hydrophobicity, not porosity. Conversely, Douglas fir biochars took up more water than hazelnut shell biochars due to greater porosity. Thus, designing biochars for water-holding applications requires two considerations: (a) creating sufficient porosity through feedstock selection, and (b) determining a production temperature that reduces hydrophobicity to an acceptable level.

02 LIQUID FUELS

Sources, properties, recovery

14/03068 A new solvent-based enhanced heavy oil recovery method: cyclic production with continuous solvent injection

Jiang, T. *et al. Fuel*, 2014, 115, 426–433.

This paper presents a new enhanced heavy oil recovery (EHOR) process, cyclic production with continuous solvent injection (CPCSI). In this process, a vaporized solvent near its dew point is continuously injected into the reservoir to maintain reservoir pressure and also supply extra gas drive to flush the diluted oil out through an injector that is located on the top of the reservoir; while a producer, which is located at the bottom of the reservoir, is operated in a shut-in/open cyclic way. A series of experiments have been conducted to evaluate the CPCSI performance. The recovery factors (RFs) are up to 85% of original oil in place in one-dimensional tests, and the RF is improved by 11% by using the two-dimensional (2-D) lateral CPCSI, compared with the traditional 2-D lateral VAPEX. Well configurations and the producer shut-in/open scenarios are key optimization factors that affect the CPCSI performance. Experimental results show that the foamy oil flow and solvent trap are the two major EHOR mechanisms for enhancing the oil production rate during the production period. In comparison with continuous injection process, such as vapour extraction (VAPEX), and cyclic injection process, such as cyclic solvent injection, CPCSI offers free gas driving, and the reservoir pressure is maintained during the producer opening period so that the diluted oil viscosity is kept low. This work shows that CPCSI could be an alternative optimization production scenario for applying solvent based *in situ* EHOR techniques for heavy oil reservoirs in western Canada.

14/03069 Characterization of the oil shale products derived via topochemical reaction method

Sun, Y. *et al. Fuel*, 2014, 115, 338–346.

In this study, the topochemical reaction strategy, utilizing Huadian oil shale to produce shale gas, liquid, and solid residues, has been demonstrated. Thermogravimetric analysis, Fourier transform-infrared spectroscopy, X-ray diffraction, gas chromatography–mass spectrometry, and scanning electron microscopy were performed to characterize the products obtained at different temperatures. Furthermore, the mechanisms of the topochemical reaction were proposed based on the experimental results and literature. During the topochemical reaction process, it was noted that the conversion of kerogen to bitumen began at approximately 270 °C. Three distinct reactions were identified in the kerogen–bitumen-oil/gas process, namely, low-temperature, moderate-temperature, and high-temperature oxidation. Shale gas and liquid were predominantly produced in the range of 400–500 °C. In this topochemical reaction strategy, oil shale was partially oxidized to carbon dioxide and water in the presence of small quantities of air, and thus a large amount of heat was produced for further self-pyrolysis. The topochemical reaction of oil shale is a chemical heat-enhanced process that not only conserves energy but also decomposes the oil shale more thoroughly.

14/03070 Flame sheet model for the burning of a low-volatility liquid fuel in a low-permeability medium under low rates of strain

Kokubun, M. A. E. and Fachini, F. F. *Combustion and Flame*, 2013, 160, (12), 2783–2799.

This work analyses a diffusion flame established in a low-permeability medium. A low-strained impinging jet of oxidant against a pool of low-volatility liquid fuel is the considered geometry. Owing to the differences on the transport properties of gas, liquid and solid, the problem presents physical processes occurring in different length scales. The authors perform an asymptotic analysis in order to obtain the profiles of temperature and species concentration in each length scale. As a result of the low-permeability feature of the medium, the velocity field is determined mainly by the gradient pressure (Darcy equation). The viscous effects become confined into small regions near the stagnation-point and the liquid–fuel interface. The effects of porosity, fuel Lewis number, strain-rate and liquid–fuel volatility on the flame temperature, flame position and vaporization rate are discussed. It is shown that the low-permeability medium is necessary in order to sustain the vaporization process of the low-volatility liquid fuel, as it enhances the heat transfer to the fuel reservoir. This model is valid for high rates of interphase heat exchange and low rates of strain.

14/03071 Organic petrographic characteristics of Tertiary (Oligocene–Miocene) coals from eastern Malaysia: rank and evidence for petroleum generation

Hakimi, M. H. *et al. International Journal of Coal Geology*, 2013, 120, 71–81.

Oligocene to Miocene coals from eastern Malaysia were analysed to evaluate their regional ranks, and petroleum generative potential. The current study performs organic geochemical characteristics of the coals and identifies macerals based on their organic petrographic characteristics as observed under reflected white light and blue light excitations. The coals are characterized by relatively high hydrogen index values between 282 and 516 mg HC/g total organic carbon. This indicates that these coals are dominated by type II to mixed type II–III kerogens, and are thus considered to be generated mainly oil-prone and limited gas-prone. This is supported by the presence of significant amounts (11–31% by volume) of oil-prone liptinite macerals. Suberinite is among the most common of the oil-prone liptinite macerals in coals. These coals likely are to be potential petroleum sources, thus, where the former is abundant, waxy oils and naphthenic oil might be expected. This has been supported by the distribution of n-alkyl chains within kerogen pyrolysates, predicting the generation of a mainly paraffinic and paraffinic–naphthenic–aromatic (P–N–A) high wax oils. The coals are thermally early-mature and coal rank in the region is subbituminous A to high-volatile bituminous C, possessing vitrinite reflectance in the range of 0.50–0.67%. This maturity has a considerable influence on the proximate analysis, particularly on a relatively low moisture content and relatively high fixed carbon and low volatile matter contents. Although these onshore coals are thermally early mature for petroleum generation, the stratigraphic equivalent of these sediments offshore is known to have been buried to deeper depth and could therefore act as potential source rock for mainly oil with minor amounts of gas.

14/03072 Rheology of bitumen: effects of temperature, pressure, CO_2 concentration and shear rate

Behzadfar, E. and Hatzikiriakos, S. G. *Fuel*, 2014, 116, 578–587.

The effects of temperature, pressure, dissolved carbon dioxide and shear rate on the rheological response of bitumen are investigated by using the reduced variable method at a temperature range from −10 to 180 °C and pressures up to 15 MPa. A state-of-the-art pressure cell set-up was utilized with a stress/strain controlled rheometer (Anton–Paar, MCR-501) to collect the experimental data on the Athabasca bitumen–CO_2 mixture. The double-log model is found to be the most accurate equation in describing the effect of temperature on the viscosity of bitumen over a wide range of temperature while the Barus model with the temperature-dependent parameter is found to be the most appropriate correlation to represent the effect of pressure. Excluding the effect of overhead pressure, the Fujita–Kishimato equation, resulting from the free volume concept modelling, is employed to account for the effect of dissolved CO_2 on the viscosity of the bitumen–CO_2 mixture more precisely. Moreover, a psuedoplastic model with a zero-shear viscosity is more rational to consider the effect of shear rate on the flow properties of the bituminous mixtures. The experimental conditions are carefully considered to avoid introducing flow instabilities into the mixture. It is demonstrated that the rheological properties of bitumen are more sensitive to the variables at lower temperatures.

14/03073 The octane numbers of ethanol blended with gasoline and its surrogates

Foong, T. M. *et al. Fuel*, 2014, 115, 727–739.

This paper reports the research (RON) and motor (MON) octane numbers of ethanol blended with production gasoline, four gasoline surrogates, *n*-heptane, isooctane and toluene. The ethanol concentration was varied from 0% to 100%, resulting in a clear picture of the variations of the RONs and MONs in all cases. Of initial interest are the RONs and MONs of ethanol blended with an Australian production gasoline and with several US production gasolines. The observed differences then prompt a systematic study of the variation in the RONs and MONs of ethanol blended with four gasoline surrogates, as well as with *n*-heptane, isooctane and toluene. Both *n*-heptane, isooctane and their primary reference fuels are shown to blend synergistically with ethanol, whilst toluene blends antagonistically. Consistent with these trends, a progressive increase in the toluene content in toluene reference fuels (TRFs) of a constant RON results in increasingly linear ethanol/TRF blending. Together, these results show that the antagonism of ethanol's blending with toluene acts against its synergism with isooctane and *n*-heptane, and more broadly suggest that the antagonism of ethanol's blending with aromatics may act against its synergism with paraffins. If correct, this explains trends observed both in the literature and in this study, and has implications for fuel design.

14/03074 The relationship between micro-Raman spectral parameters and reflectance of solid bitumen

Zhou, Q. *et al. International Journal of Coal Geology*, 2014, 121, 19–25.

Solid bitumen occurs widely in the Early Paleozoic and Precambrian strata and its reflectance is a generally-accepted indicator for thermal maturity. Even though some recent papers have been published concerning the Raman characteristics and spectral parameters of solid bitumen, a systematic investigation on the relationship between the Raman spectral parameters and thermal maturity of solid bitumen is still lacking. In this study, a low maturity solid bitumen sample was pyrolysed under laboratory-controlled conditions to obtain a suite of artificial bitumen samples with different maturities (BRo = 1.1–4.81%), which are used to investigate the relationships between Raman spectral parameters and reflectance of solid bitumen. The Raman spectral parameters of the artificial bitumens, including band position (W_D and W_G), band separation (RBS), full width at half maximum (FWHM-D and FWHM-G), and band intensity ratio (I_D/I_G) are all related to the bitumen reflectance, but with considerably different correlations, constrained apparently by thermal maturity. Linear regressions were performed between these parameters and bitumen reflectance, and two parameters with higher correlation were selected. They are RBS (within 1.5–3.5% of BRo) and I_D/I_G (within 3.0–5.0% of BRo), with a correlation coefficient as high as 0.97. It is believed that the two Raman spectral parameters of solid bitumen will be of significant practical use for the maturity assessment of the Early Paleozoic and Precambrian strata when standard measurement and curve fitting procedures are utilized.

Transport, refining, quality, storage

14/03075 A practical method for the separation of high quality heavy oil and bitumen samples from oil reservoir cores for physical and chemical property determination

Bennett, B. *et al. Fuel*, 2014, 116, 208–213.

This study describes a mechanical extraction method, referred to here as 'the plunger', for the recovery of heavy oil and bitumen samples, equivalent to produced oil samples, from clastic and carbonate reservoir cores. The authors demonstrate the efficacy of the plunger relative to the centrifugation method through comparing the physical properties and chemical compositions of the heavy oils and bitumens recovered from oil sands cores. Over the dead oil viscosity range from 21,000 to 1.4×10^6 cP at 20 °C and 9.6×10^6 cP at 25.5 °C, the plunger consistently yielded correspondingly lower viscosity oils compared to the oils recovered by centrifugation from the same sample material, as well as lower sediment fines and water content. For an example of extremely viscous oil, the plunger yielded 3.3 g of 9.6×10^6 cP oil (25.5 °C), while centrifugation produced only 50 mg of fluid, adequate for geochemical analysis but insufficient for viscosity and density determination. The plunger has many advantages that favour its use over centrifugation such as successful recovery of highly viscous oil from cores, lower oil sediment fines/water content and faster sample extraction (typically 30 min to 1 h versus 2 h). The plunger has also been operated at the rig site to generate oil viscosity logs immediately following core recovery (prior to or during petrophysical logging) affording real time data acquisition to support decisions for conducting production flow tests while drilling rigs are onsite. Incidentally, due to the improved preservation of physical properties controlling volatile liquid components, repeated plunging of larger volumes of sample core can be used to recover large enough volumes of heavy oil or bitumen for pressure, volume and temperature (PVT) or specialist assay analysis. Since the plunger is operated under a sealed system the device may be configured in such a way to interface with a PVT cell.

Gas introduced into the plunger system ultimately can lead to the production and collection of 'enlivened oils' for viscosity measurements.

14/03076 An experimental study of mechanical behavior of coiled tubing in pipelines

Guan, F. *et al. Applied Ocean Research*, 2014, 44, 13–19.

Coiled tubing operating systems can improve the efficiency of offshore oil and gas exploration with a wide prospect of application. Coiled tubing is commonly subjected to complex loading inside the pipeline or wellbore. Through experimental research, the experimental explanations of actual pipe depth the coiled tubing goes into, buckling, lock-up, release, etc., can be derived. In this paper, the method of combined numerical calculation and experimental validation was used to study coiled tubing buckling inside the pipeline or wellbore. The geometric parameters of the experimental system are presented. A test bench including a vertical segment, a bending segment, a horizontal segment and an end-loading unit were designed. The experiments were carried out using rubber rods and steel wires with three different diameters, bending segment of two kinds of lengths, and terminal constraints of the free end, fixed end and loading end. Experimental phenomena such as sinusoidal buckling, helical buckling, lock-up, pitch reversal, yield of head and load jumps in end loading experiments were analysed. The experimental results were in good agreement with the numerical results. The load jumps in end loading experiments and radial gap affect helical buckling and lock-up process. Moreover, the decision criterion of helix lock-up in the field operation is proposed, which can provide a guide for engineering practice.

14/03077 Column generation heuristics for ship routing and scheduling problems in crude oil transportation with split deliveries

Nishi, T. and Izuno, T. *Computers & Chemical Engineering*, 2014, 60, 329–338.

We propose a column generation based heuristic algorithm to solve a ship routing and scheduling problem for crude oil transportation with split deliveries. The problem is to find an optimal assignment and sequence and loading volume of demand simultaneously in order to minimize the total distance satisfying the capacity of tankers. The problem can be considered as a multi-product heterogeneous fleet split pickup ship routing problem with finite capacity and loading constraints. An efficient heuristic algorithm based on the column generation method is developed to generate a feasible solution taking into account of practical constraints. The performance of the proposed method is compared with the branch and bound algorithm and that of human operators. Computational results demonstrate the effectiveness of the proposed algorithm for a real case.

14/03078 Effects of dilution conditions on diesel particle size distribution and filter mass measurements in case of marine fuels

Ushakov, S. *et al. Fuel Processing Technology*, 2014, 118, 244–253.

Particle emission characteristics were studied from heavy-duty diesel engine operating on fuels with sulfur levels relevant to marine operation, i.e. 0.05% S and 3% S, respectively. Effects of primary dilution temperature (PDT) and primary dilution ratio (PDR) were investigated together with effect of filter media and time of filter conditioning. PDT increase was found slowing down nucleation rate due to increase of saturation vapour pressures of volatile species. In turn, increasing PDR reduces partial pressure of exhaust species and hence weakens both homogeneous and heterogeneous nucleation. All these effects are amplified by high sulfur content in marine fuels which increases available amount of nucleation-prone vapour-phase semi-volatile compounds. At the same time, water condensation artifact was observed at PDR = 3. No filter type was found to be overwhelmingly superior as certain positive and/or negative measurement artefacts are inherently associated with all filter materials. The filter conditioning time was also found to cause substantial particulate matter (PM) mass variation, as control over volatile organic compounds take up from (or lost to) laboratory air and hydration of sulfuric acid is required. The standard 24-hour conditioning time was found insufficient to reach complete PM mass equilibrium, so longer time is required when measuring from high-sulfur fuels.

14/03079 Modeling for the optimization of layout scenarios of cluster manifolds with pipeline end manifolds

Wang, Y. *et al. Applied Ocean Research*, 2014, 46, 94–103.

The pipeline end manifold (PLEM) is an important subsea facility, which can greatly reduce the cost and risk of the development scenarios of deepwater oil and gas fields by declining the number of export pipelines and risers. However, the employment of PLEMs is a multidiscipline task involving substantial financial and technical factors. Due to various uncertainties of influencing factors, the evaluation process may take several months or years by the engineers with rich project experience. Thus, how to develop quantified reference tools using mathematical models to assist engineers in efficiently making their crucial decisions is essential. In this paper, the optimization of the layout scenarios of cluster manifolds with PLEMs is discussed, where a proposed mathematical model and its dedicated algorithm are illustrated. The optimal solution at the lowest cost can be obtained through in-house routine in MATLAB, including the optimal layout scenario, the number and locations of PLEMs, and the connection relations. Besides, the numerical simulations are performed to demonstrate the validity of the proposed mathematical model and its algorithm. The results show that this optimization layout problem in engineering can be described accurately by the presented mathematical model and the convergence rate of the given algorithm is efficient.

14/03080 Optimal design of advanced drop-in hydrocarbon biofuel supply chain integrating with existing petroleum refineries under uncertainty

Tong, K. *et al. Biomass and Bioenergy*, 2014, 60, 108–120.

This paper addresses the optimal design of an advanced hydrocarbon biofuel supply chain integrated with existing petroleum refineries. Three major insertion points from the biofuel supply chain to the petroleum refineries are investigated and analysed, including bio-intermediates co-processed with crude oil, bio-intermediates co-processed with refinery intermediates, and finished biofuels blended with conventional petroleum products. A multiperiod, mixed-integer linear programming model is proposed that accounts for diverse conversion pathway, technology, and insertion point selections, biomass seasonality, geographical diversity, biomass degradation, demand distribution and government incentives. This model simultaneously optimizes the supply chain design, insertion point selection, and production planning. In addition, the conversion rate, operation cost associated with insertion points in petroleum refinery, as well as the biomass availability and product demand are modelled as fuzzy numbers to account for the data uncertainty. A fuzzy possibilistic programming approach is applied to this model, where possibility, necessity and credibility measures are adopted according to the decision makers' preference. This model is illustrated by the county level case study of Illinois, USA. Compared to traditional biofuel supply chains, advanced hydrocarbon biofuel supply chain integrating with existing petroleum refinery infrastructure significantly reduces capital cost and total annualized cost.

14/03081 Optimizing the biodesulfurization of gas oil by adding surfactants to immobilized cell systems

Dinamarca, M. A. *et al. Fuel*, 2014, 116, 237–241.

Biodesulfurization is a microbial biocatalytic process that removes sulfur from hydrocarbons. Because this bioprocess can be influenced by substrate bioavailability, this study considers the effect of natural and synthetic surfactants on biodesulfurization using metabolically active and immobilized bacterial cells. Surfactants are surface-active molecules that improve the solubility of solids or water-insoluble substrates. Metabolically active cells of the desulfurizing strain *Rodococcus rhodochrous* IGTS8 were immobilized on silica, alumina and sepiolite by adsorption. The desulfurization activity was determined in the presence of biological and synthetic surfactants. The results indicate that adding surfactants to the catalytic system formed by non-immobilized or immobilized cells increases the desulfurization of dibenzothiophene and gas oil. A major effect was observed when a microbial biosurfactant was used to improve the interaction between insoluble sulfured substrates and the respective immobilized biocatalytic systems. The bioavailability of the sulfured substrates improved because of micelle formation. The use of a biocatalytic system conformed by immobilized cells, biological surfactants and sulfured substrates can be an improved methodology for biodesulfurization that makes a potential application for industry more feasible.

14/03082 Performance, combustion and emission characteristics of n-butanol additive in methanol–gasoline blend fired in a naturally-aspirated spark ignition engine

Siwale, L. *et al. Fuel Processing Technology*, 2014, 118, 318–326.

The aim of the study was to compare the effects of dual alcohols (n-butanol and methanol) with single alcohol (methanol) blended in gasoline fuel (GF) against performance, combustion and emission characteristics. Problems arise in the fuel delivery system when using the highly volatile methanol–gasoline blends. This problem is reduced by adding n-butanol to methanol–gasoline blends. However, the satisfactory engine performance of the dual alcohol–gasoline blends need to be proved. The test fuels were GF, blend M53b17 (53% methanol, 17% n-butanol and 30% GF by volume), M20 and M70. The blend M53b17 was selected to match the vapour pressure of GF, whereas M70 to match the total alcohol content in the blend. The test fuels were a lean mixture with excess-air ratio of $\lambda = 1.1$. The experiments were conducted on a naturally-aspirated, spark ignition engine. The brake thermal efficiency improved whereas the exhaust gas temperature of the blends reduced, which is a benefit that reduces compression work. The regulated emissions were also reported. The

blend M53b17 was recommended in preference to M70 because the former had shortened combustion duration, high-energy content and its vapour pressure was selectively matched to that of GFs.

14/03083 Polymer-supported ionic liquids: synthesis, characterization and application in fuel desulfurization

Lin, Y. *et al. Fuel*, 2014, 116, 273–280.

Ionic liquids (ILs) were considered to be immobilized on solid supports to overcome the problems of the pure ILs in fuel desulfurization. Using Merrifield resin as a solid support, four polymer-supported imidazole ionic liquids (PSILs) with different lengths of alkyl chain linkers were prepared by covalent binding and the structures were characterized by Fourier transform infrared spectroscopy, elemental analysis, ^{13}C solid state magic-angle-spinning nuclear magnetic resonance spectroscopy, scanning electron microscopy and energy dispersive spectrometry. The results suggested the series PSILs had been obtained. Then, the PSILs were investigated to remove thiophene (TS) or dibenzothiophene (DBT) from model gasoline (cyclohexane/TS or DBT) under certain conditions: (1) PSILs showed better sulfur removal ability than the Merrifield resin, PS[unmim][BF_4] showed the best percentage sulfur removal which could up to $\geq$30% due to the longest alkyl chain linker and the smallest particles. (2) The sulfur removal selectivity of DBT was better than TS for its higher density aromatic π-electrons. The Sips adsorption isotherms model fitted the adsorption experimental data of PS[unmim][BF_4] for TS and DBT at 303.15 K best. Finally, the adsorption mechanism was discussed.

14/03084 Review of fuel oil quality and combustion of fast pyrolysis bio-oils from lignocellulosic biomass

Lehto, J. *et al. Applied Energy*, 2014, 116, 178–190.

Fast pyrolysis bio-oils are completely different from petroleum fuels and other bio-fuels available in the market in regard as to both their physical properties and chemical compositions. When the unusual properties of these bio-oils are carefully taken into account in system and burner design, their combustion without a pilot flame or support fuel is possible on an industrial scale. The aim of this paper is to review the work done on combustion of fast pyrolysis bio-oils and highlight the latest and most important findings of its combustion from laboratory fundamentals to industrial scale. The main focus of the paper is on the bio-oil burner applications. In recent industrial scale bio-oil combustion tests, bio-oil has been found to be technically suitable for replacing heavy fuel oil in district heating. In addition, it has also been found out that limited possibilities for further lowering particulate emissions exist, since the majority of the particulates are typically incombustible matter. Curves for NO_x emissions of fast pyrolysis bio-oil combustion for air-assisted atomization burners are presented in the paper. Current burner designs are quite sensitive to the changes in the quality of the bio-oil, which may cause problems in ignition, flame detection and flame stabilization. Therefore, in order to be able to create reliable bio-oil combustion systems that operate at high efficiency, bio-oil grades should be standardized for combustion applications. Careful quality control, combined with standards and specifications, all the way from feedstock harvesting through production to end-use is recommended in order to make sure that emission targets and limits in combustion applications are achieved. Also the cost-effectiveness of the total package is extremely important.

14/03085 Separation techniques in butanol production: challenges and developments

Abdehagh, N. *et al. Biomass and Bioenergy*, 2014, 60, 222–246.

The rising cost of crude oil combined with the depletion of the resources, political instability in oil producing countries, and the desire to reduce the current dependence on imported oil are some of the reasons that have motivated the different waves of interest for renewable and sustainable fuels. In addition to bioethanol and biodiesel, biobutanol is attracting significant interest as a biofuel mainly due to the recent advances in biotechnology for its production. Biobutanol has lower water miscibility, flammability, and corrosiveness than ethanol, and has the enviable advantage to be able to directly replace gasoline in car engines without requiring modifications. Butanol can be produced from a wide variety of waste biomass feedstock which does not compete with food. In butanol bioproduction, the most widely used microorganisms for acetone–butanol–ethanol fermentation are anaerobic bacteria such as the solventogenic Clostridia including *Clostridium acetobutylicum* and *Clostridium beijerinckii*. However, the production of biobutanol via fermentation is facing significant engineering challenges due to the very low final concentration and low yield due to the severe butanol toxicity to microorganisms. It is therefore important to find an efficient separation technique to recover butanol at the end of fermentation or during the fermentation to reduce the level of toxicity and prolong the fermentation. In this paper, the main butanol separation techniques such as adsorption, gas stripping, liquid–liquid extraction, perstraction, reverse osmosis and pervaporation were discussed. It was concluded that adsorption and pervaporation are the separation techniques that offer the most potential for butanol separation from dilute solutions.

14/03086 Synthesis and evaluation of alkyl acrylate-vinyl acetate-maleic anhydride terpolymers as cold flow improvers for diesel fuel

Feng, L. *et al. Fuel Processing Technology*, 2014, 118, 42–48.

Four different alkyl chain length of n-alkyl acrylate-vinyl acetate-maleic anhydride terpolymers were synthesized by radical polymerization and characterized by Fourier transform infrared spectroscopy and gel permeation chromatography. To further the development of these cold flow improvers, their performance mechanism was studied. The carbon number distribution of n-alkanes in $0^{\#}$ diesel fuel was analysed by gas chromatography. The rheological behaviour and crystallization behaviour of diesel fuel treated with and without additives were studied using an advanced rheometer and an optical microscope. The results show that the influence of alkyl chain length of terpolymer was closely related to the content of the corresponding n-alkane in the diesel fuel. The formation of a three-dimensional network directly determines the solidifying point of diesel fuel, while the cold filter plugging point is closely related to the size, shape and aggregation of wax crystals, thus the effects of cold flow improver on the solidifying point and cold filter plugging point of diesel fuel are sometimes inconsistent. Moreover, a good diesel cold flow improver should be detrimental to the formation of three-dimensional network and detrimental to the formation of too large wax crystals or wax crystals tending to form large clusters.

Economics, business, marketing, policy

14/03087 A review of current technology for biodiesel production: state of the art

Aransiola, E. F. *et al. Biomass and Bioenergy*, 2014, 61, 276–297.

This study reviews various technologies that have been used for biodiesel production with a view to comparing commercial suitability of these methods on the basis of available feedstocks and associated challenges. This review shows that while emphasis is on the use of micro alga oil sources, the viability of the economics of the process is still in doubt. Homogenously catalysed processes are the conventional technologies. However, their large-scale applicability is compromised due to their characteristic challenges. Batch processes and continuous processes are used for industrial purposes with typical capacity of 7.26–7.5 and 8–125 Gg y^{-1} respectively, and heterogeneous catalysis may be sustainable for the continuous processes. Heterogeneous catalysts from renewable sources may be both environmentally and economically viable. Reactive distillation has the major advantage of combining the reaction and separation stages in a single unit, thereby significantly reducing capital costs and increasing opportunities for heat integration. This paper is a comprehensive overview of current technologies and appropriate options for scale-up development, providing the basis for a proposal for the exploitation of heterogeneous catalysts from natural sources to optimize biodiesel production.

14/03088 Forecasting Brazil's crude oil production using a multi-Hubbert model variant

Saraiva, T. A. *et al. Fuel*, 2014, 115, 24–31.

Different methodologies have been applied to forecast oil production curves in many regions or countries. The scientific literature indicates that curve-fitting models, especially the approach of Hubbert, are a simple and suitable tool for first-order projections of future production. This is particularly true when data for ultimately recoverable resources (URR) are uncertain and producers are price-takers. This study estimated Brazil's oil production curves, according to different URR scenarios (P95, P50 and P5), applying a modified multi-Hubbert model. This model improved the classic methodology by adding productive cycles and allowing the revision of the assumption that production rate is strictly proportional to the first power of both depletion and information effects. Findings show that, without considering the recent discoveries in pre-salt layers, Brazil's peak oil should hover between 2.37 Mb/d (2015), 3.33 Mb/d (2022) and 6.59 Mb/d (2035), depending on URR scenarios. The accuracy of the fitting related to the observed data from 1954 to 2012 gave a relative standard deviation of less than 2.5%. Considering pre-salt contingent resources, Brazil's peak oil would be fatter and range from 4.85 Mb/d (2027) to 8.24 Mb/d (2047) depending on the hypotheses made. This last result is, however, highly uncertain.

14/03089 How do oil producers respond to oil demand shocks?

Güntner, J. H. F. *Energy Economics*, 2014, 44, 1–13.

This paper analyses the response of international oil producers to demand-induced changes in the price of crude oil during 1975–2011, focusing on potential differences between members of the Organization of Petroleum Exporting Countries (OPEC) and non-OPEC countries. The goal is to derive consistent estimates of the short-run price elasticity of crude oil supply at the country level. It was found that oil producers hardly respond to demand shocks within the same month, and that the corresponding impact price elasticities of supply are statistically indistinguishable from zero. While there is little evidence of differences in the dynamic responses to a typical flow demand shock, on average over the sample period, OPEC members seem to curtail production in response to a speculative demand shock, whereas non-OPEC production expands significantly. Flow and speculative demand shocks account for a non-trivial fraction of the total variability in country-level crude oil supply.

14/03090 On the economic determinants of oil production: theoretical analysis and empirical evidence for small exporting countries

Cologni, A. and Manera, M. *Energy Economics*, 2014, 44, 68–79.

In this paper, decisions regarding production in oil-exporting countries are studied by means of theoretical analysis and empirical investigation. In particular, this study aims at describing the relationship between oil production levels and changes in the world oil demand and prices. Intertemporal production decisions by a representative oil producer are modelled by means of a partial equilibrium model. In this theoretical model, oil producers are subject to exogenous shocks in world oil consumption and prices. Oil companies can change output levels only by incurring a fixed cost. Results from the simulation of this model show a strong relationship between oil production and changes in world oil consumption. On the contrary, the effects of changes in real oil prices on oil production decisions seem to be much lower. Results from the simulation of the theoretical model are then empirically investigated using time-series econometric techniques. The empirical evidence supports the hypothesis that oil-producing countries are characterized by different responses to changes in world oil demand and in real oil prices. For many countries, production rapidly adjusts to changes in consumption whereas responses of oil production to innovations in real oil prices are found to be not statistically significant. In addition, when non-linearities in the relationship between world oil demand, prices and output levels are allowed for, evidence of asymmetric effects of shocks to exogenous variables on output levels is found for some countries.

14/03091 The differential effects of oil demand and supply shocks on the global economy

Cashin, P. *et al. Energy Economics*, 2014, 44, 113–134.

This study employs a set of sign restrictions on the impulse responses of a global vector autoregressive model (GVAR), estimated for 38 countries/regions over the period 1979Q2–2011Q2, as well as bounds on impact price elasticities of oil supply and oil demand to discriminate between supply-driven and demand-driven oil-price shocks, and to study the time profile of their macroeconomic effects across a wide range of countries and real/financial variables. The authors show that the above identification scheme can greatly benefit from the cross-sectional dimension of the GVAR – by providing a large number of additional cross-country sign restrictions and hence reducing the set of admissible models. The results indicate that the economic consequences of a supply-driven oil-price shock are very different from those of an oil-demand shock driven by global economic activity, and vary for oil-importing countries compared to energy exporters. While oil importers typically face a long-lived fall in economic activity in response to a supply-driven surge in oil prices, the impact is positive for energy-exporting countries that possess large proven oil/gas reserves. However, in response to an oil-demand disturbance, almost all countries in this sample experience long-run inflationary pressures, an increase in real output, a rise in interest rates, and a fall in equity prices.

Derived liquid fuels

14/03092 Biodiesel via supercritical ethanolysis within a global analysis 'feedstocks-conversion-engine' for a sustainable fuel alternative

Coniglio, L. *et al. Progress in Energy and Combustion Science*, 2014, 43, 1–35.

The challenges in reducing the world's dependence on crude oil and the greenhouse gas accumulation in the atmosphere, while simultaneously improving engine performance through better fuel efficiency and reduced exhaust emissions, have led to the emergence of new fuels, with formulations blending petrodiesel, biodiesel, bioethanol and water in various proportions. In parallel, the sustainability of the new biofuel industries also requires to maintain a high level of biodiversity while playing on techno-diversity, using a variety of resources that do not compete with edible crops (nor by using arable land for energy crops or food crops for energy production) and flexible conversion technologies satisfying the eco-design, eco-energy and eco-materials criteria. In addition, it would be relevant to consider blending ethyl biodiesel, instead of methyl biodiesel, with petrodiesel, particularly if the fuel formulation is completed with bioethanol (or even water). The supercritical ethanolysis of lipid resources to produce ethyl biodiesel is a simple but efficient route that should have the potential to satisfy the sustainability criteria if analysed holistically. Therefore, this review focuses specifically on the production of ethyl biodiesel via triglyceride supercritical ethanolysis within a global analysis 'feedstocks-conversion-engine'. The scientific and technical bottlenecks requiring further development are highlighted by emphasizing (i) the kinetic and thermodynamic aspects (experiments and modelling) required for the process simulation, the results of which aim at securing the life cycle assessment, first at the process level and then at the fuel level; (ii) the proposals to improve the supercritical process performance in terms of eco-material and eco-energy; (iii) the impacts of ethyl vs methyl biodiesel fuels and of biodiesel–ethanol–petrodiesel blends (with or without water) on the diesel engine emissions and performance; (iv) the technological flexibility of the supercritical process allowing its conversion toward production of other key products. Finally, built on the state-of-the-art review, a new R&D direction combining supercritical ethanolysis of lipids with the addition of CO_2, glycerol recovery, and cogeneration, according to the biorefinery concept, is proposed and discussed.

14/03093 Catalytic hydroliquefaction of charcoal CCB (copper, chromium and boron)-treated wood for bio-oil production: influence of CCB salts, residence time and catalysts

Kinata, S. E. *et al. Applied Energy*, 2014, 115, 57–64.

Thermochemical processes offer a feasible option for wood waste management and the recovery of a variety of useful chemicals. In this paper, hydroliquefaction with the use of catalysts was optimized to provide bio-oil from treated wood by reducing gaseous emissions of copper, chromium and boron (CCB, hazardous materials). In addition, the influence of CCB salts, catalysts (Al_2O_3, Na_2CO_3, MgO and $CaCO_3$) and residence time on the hydroliquefaction process was investigated. For this, hydroliquefaction of charcoal obtained by slow pyrolysis of CCB-treated wood was conducted under hydrogen pressure in presence of tetralin. The results showed that CCB salts and catalysts increase the yield of bio-oil compared to hydroliquefaction of charcoal from untreated wood. It was also observed, that the use of catalysts improves the residence time during the process. Among the catalysts employed, Al_2O_3 appears to be the most effective. Furthermore Na_2CO_3 promotes the formation of gaseous species particularly CH_4. Analyses of hazardous materials in charcoal residue (coke) illustrate their transfer to the bio-oil with the increase of bio-oil yield and residence time except when Al_2O_3 was using. The bio-oil obtained contains aromatic compounds.

14/03094 Cornstalk liquefaction in methanol/water mixed solvents

Zhu, W.-W. *et al. Fuel Processing Technology*, 2014, 117, 1–7.

Cornstalk liquefaction (CSL) in methanol, water or methanol/water mixed solvents was studied at 250–320 °C. Each reaction mixture was separated into extract 1 (E_1, including the solute in filtrate and methanol-extractable portion), extract 2 (E_2, methanol-inextractable but isometric carbon disulfide/acetone-extractable portion) and residue (isometric carbon disulfide/acetone-inextractable portion) by filtration and sequential extraction with methanol and isometric carbon disulfide/acetone mixed solvent. The cornstalk, E_1, E_2 and the residues were analysed using a Fourier transformation infrared spectrometer and each E_1 was analysed using a gas chromatography/mass spectrometer. The microstructures of the cornstalk and its derived residues were observed with a scanning electron microscope. The results show that methanol and water exhibited a synergic effect on the CSL. The isometric methanol and water mixed solvent was found to be most effective for CSL at 300 °C for 30 min. Under such conditions, the total yield of gases, E_1 and E_2 and the yield of E_1 reached 88.1% and 52.4%, respectively. The yields decreased as the temperature or time was further increased, suggesting that some of the extractable species were repolymerized at higher temperatures or for prolonged time. E_1 consisted of hydrocarbons, alkanols, tetrahydrofuranylmethanols, arenols, methoxyalkanes, methoxyarenes, ketones, carboxylic acids, esters, chloromethylbenzenes, nitrogen-containing species and several other species.

14/03095 DIRECT CTL: innovative analyses for high quality distillates

Quignard, A. *et al. Fuel*, 2013, 114, 172–177.

Distillate liquid yields from high hydrogen pressure catalytic conversion of coal processes, called direct coal liquefaction (DCL), are typically high at 4–5 bbl/T coal on a dry ash free basis for the best available DCL processes, making them an attractive option to produce transportation fuels from coal. These yields are significantly higher than using the so-called indirect coal-to-liquid route, i.e. gasification plus Fisher–Tropsch synthesis. Nevertheless, DCL products are often considered as relatively low-quality products and their chemical structure is not well known. This work focuses on the physical/chemical standardized analyses and innovative detailed characterization of the properties and the unique composition of jet fuel and Diesel cuts obtained by DCL before and after hydroprocessing. It shows that 100% high-quality fully desulfurized Jet A, Jet A-1 or JP-8 aviation fuels can be obtained when using the appropriate hydrocracking conditions. It also shows that the Diesel cut obtained from the same upgrading process can be used as a high-quality component for transportation fuels with <5 ppm sulfur, exhibiting a very specific chemical structure that is accompanied by excellent cold flow properties and good combustion characteristics. This innovative detailed characterization of hydroprocessed DCL jet fuel and Diesel cuts was provided using a two-dimensional gas chromatography method developed within the IFP Energies nouvelles laboratories.

14/03096 Gas hydrate phase equilibrium in porous media: an assessment test for experimental data
Ilani-Kashkouli, P. *et al. Fluid Phase Equilibria*, 2013, 360, 161–168.
In this paper, experimental dissociation data for carbon dioxide, methane and ethane hydrates in the presence of pure water and different types of porous media (mesoporous silica gel, porous glass and silica gel) were assessed, in order to detect any suspect or doubtful data. The leverage statistical model algorithm was used in which determination of the statistical hat matrix, sketching of the Williams plot, and calculation of the residuals of selected correlation results are included. Gas hydrate dissociation conditions in porous media were predicted using of the least squares support vector machine algorithm. This study provides an overview on the quality of existing experimental data (outlier detection), as well as the applicability domain of the model employed.

14/03097 Hydro-liquefaction of thermal dissolution soluble fraction of Shenfu subbituminous coal and reusability of catalyst on the hydro-liquefaction
Shui, H. *et al. Fuel*, 2014, 115, 227–231.
The thermal dissolution (TD) of a Chinese subbituminous coal was carried out with different solvents, and five thermal dissolution soluble fractions (TDSFs) with different thermal dissolution soluble yield (TDSY) were obtained. The catalytic hydro-liquefactions of the five TDSFs suggested that the TDSFs obtained have higher liquefaction activity compared to that of raw coal. There is no relation between the liquefaction activity of TDSF and its TDSY. The TDSF with high content of polycyclic aromatic ring systems gives lower liquefaction activity. The reusability of a solid acidic catalyst BF_3/SBA-15 used in the hydro-liquefaction of TDSF was measured. The results suggested that the reused catalyst has higher catalytic hydro-liquefaction activity compared to that of fresh catalyst. Carbon deposition in the reused catalyst slowly takes place, and the catalyst used in the catalytic liquefaction of TDSF has a good reusability. The recycled use of catalyst for the liquefaction of TDSF is capable at least four times. Therefore, it supplies a new pathway to realize high-efficiency coal liquefaction in economy due to the use of recycled high efficient catalyst in the liquefaction of TDSF.

14/03098 Hydrothermal liquefaction of barks into bio-crude – effects of species and ash content/composition
Feng, S. *et al. Fuel*, 2014, 116, 214–220.
Liquefaction of barks of white pine, white spruce and white birch was performed in ethanol–water (50 : 50, v/v) co-solvents under the initial N_2 pressure of 2.0 MPa at 300 °C for 15 min. It was found that the liquefaction efficiency, in terms of bark conversion and biocrude yield, varied significantly with bark species and ash content/composition. As far as the bark conversion was concerned, the order follows: white spruce bark (92%) > white birch bark (89%) > white pine bark (68%), which is also in good agreement with the ash content of the barks: white spruce bark (3.07%) > white birch bark (2.68%) > white pine bark (1.07%). Biocrude yield reduced in the following order: white birch bark (67%) > white spruce bark (58%) ≫ white pine bark (36%). Effects of ash content on bark liquefaction were investigated by comparing the liquefaction efficiencies between crude bark and de-ashed bark. De-ashing pre-treatment of barks in 0.5 M nitric acid efficiently decreased ash content in barks of white pine, white spruce and white birch form 1.07%, 3.07%, 2.68% to 0.67%, 0.33% and 0.32%, respectively. The de-ashing of bark decreased both bark conversion rate and biocrude yield for all barks, suggesting that the ash of the bark play catalytic roles in the bark liquefaction, which was confirmed by the addition of K_2CO_3 and $Ca(OH)_2$ into de-ashed barks. The bark-derived biocrude oils are aromatic/phenolic in nature with higher heating values of 25–39 MJ/kg. The obtained biocrude oils also have relatively lower molecular weights (M_n = 320–600 g/mol, M_w = 800–1700 g/mol, PDI = 2.2–2.9), which makes the biocrude oils promising in the applications for either biofuel or as a phenol substitute in biophenolic resins.

14/03099 Investigation on the rheological and stability characteristics of coal–water slurry with long side-chain polycarboxylate dispersant
Zhu, J. *et al. Fuel Processing Technology*, 2014, 118, 187–191.
A novel comb-like polymer, long side-chain polycarboxylate (LcPC), was designed as a dispersant for coal–water slurry (CWS) and synthesized in aqueous solution from the copolymerization of macromonomer polyethylene glycol-acrylate monoester(PA), sodium p-styrene sulfonate (SSS) and acrylamide (AM). PA was prepared by esterifying with polyethylene glycol (PEG200, 400, 600, 800, 1000, 2000) and acrylic acid (AA). The structure of LcPC was characterized. The performance of LcPC as dispersant for the low-rank China coal–water slurry (i.e. Shenfu coal) was evaluated and the dispersion mechanism was also explored. Results showed that the dispersant was a polymer with long side-chains modified by $–ArSO_3Na$ and $–CONH_2$ groups. The CWS with LcPC displayed the better rheological and stability characteristics than the traditional dispersant in stock for the low-rank China coal (i.e. the apparent viscosity and penetration ratio of CWS with 65 wt% coal and 0.4 wt% dispersant were 389 mPa s and 82.0%, respectively). The properties of the CWS can be further improved in the presence of LcPC because of not only the better electrostatic force with the coal but also the stable steric hindrance of long side-chain.

14/03100 Properties of slurries made of fast pyrolysis oil and char or beech wood
Trinh, T. N. *et al. Biomass and Bioenergy*, 2014, 61, 227–235.
The properties of slurries made of pyrolysis oil mixed with wood, char or ground char were investigated with respect to phase transitions, rheological properties, elemental compositions, and energy density. Also the pumping properties of the slurries were investigated at temperatures of 25, 40 and 60 °C and solid loadings from 0 to 20 wt%. The phase transitions of the wood slurry samples were observed at lower solid loadings compared to the char slurry samples. The apparent viscosity of the slurry samples was found to be considerably impacted by solid loading (0–20 wt%) and temperature (25–60 °C), especially in the phase transition region. The slurry viscosities with 20 wt% char loading, 20 wt% ground char loading and 15 wt% wood loading (at a shear rate of 100 s^{-1}) are 0.7, 1.0 and 1.7 Pa s, respectively at 60 °C and these values increases 1.2–1.4 times at 40 °C and 3–4 times at 25 °C. The wood, char and ground char slurry samples with 5–20 wt% solid loading obtain a volumetric energy density of 21–23 GJ/m^3. The slurry sample with 20 wt% ground char having a d_{80} of 118 μm was pumped successfully into a pressurized chamber (0–6 bar) while plugging appeared when the slurry samples with 15 wt% char having a d_{80} of 276 μm was pumped into the pressurized chamber.

03 GASEOUS FUELS

Sources, properties, recovery, treatment

14/03101 A comparison of the influence of adsorbed gases on gas stresses leading to coal and gas outburst
Sobczyk, J. *Fuel*, 2014, 115, 288–294.
The present work analyses the influence of seepage and desorption processes on the initial conditions of coal and gas mini-outbursts. A series of laboratory experiments incorporating coal briquettes and three different gases, namely carbon dioxide, methane or nitrogen were carried out. Experiments relied on mini-outburst inducement. Space and time pressure distributions along the briquettes were recorded. A comparative analysis of the results revealed that the observed differences in mini-outbursts initial conditions cannot be explained by means of a simple coal or gas property such as sorption capacity, desorption rate, seepage rate or viscosity of gas. On the contrary, the efficiency of accumulated gas-releasing processes – desorption and diffusion inside of the coal grains and seepage through the briquette coupled processes – seems to explain the observed variations.

14/03102 A dynamic prediction model for gas–water effective permeability based on coalbed methane production data

Xu, H. *et al. International Journal of Coal Geology*, 2014, 121, 44–52.

An understanding of the relative permeability of gas and water in coal reservoirs is vital for coalbed methane development. In this work, a prediction model for gas–water effective permeability is established to describe the permeability variation within coal reservoirs during production. The effective stress and matrix shrinkage effects are taken into account by introducing the Palmer and Mansoori (PM) absolute permeability model. The endpoint relative permeability is calibrated through experimentation instead of through the conventional Corey relative permeability model, which is traditionally employed for the simulation of petroleum reservoirs. In this framework, the absolute permeability model and the relative permeability model are comprehensively coupled under the same reservoir pressure and water saturation conditions through the material balance equation. Using the Qinshui Basin as an example, the differences between the actual curve that is measured with the steady-state method and the simulation curve are compared. The model indicates that the effective permeability is expressed as a function of reservoir pressure and that the curve shape is controlled by the production data. The results illustrate that the PM–Corey dynamic prediction model can accurately reflect the positive and negative effects of coal reservoirs. In particular, the model predicts the matrix shrinkage effect, which is important because it can improve the effective permeability of gas production and render the process more economically feasible.

14/03103 Experimental evaluation and ANN modeling of a recuperative micro gas turbine burning mixtures of natural gas and biogas

Nikpey, H. *et al. Applied Energy*, 2014, 117, 30–41.

Previously published studies have addressed modifications to the engines when operating with biogas, i.e. a low heating value fuel. This study focuses on mapping out the possible biogas share in a fuel mixture of biogas and natural gas in micro combined heat and power (CHP) installations without any engine modifications. This contributes to a reduction in CO_2 emissions from existing CHP installations and makes it possible to avoid a costly upgrade of biogas to the natural gas quality as well as engine modifications. Moreover, this approach allows the use of natural gas as a 'fallback' solution in the case of eventual variations of the biogas composition and or shortage of biogas, providing improved availability. In this study, the performance and emissions of a commercial 100 kW micro gas turbine (MGT) at full and part loads are experimentally evaluated when fed by varying mixtures of natural gas and biogas. The MGT is equipped with additional instrumentation, and a gas mixing station is used to supply the demanded fuel mixtures from zero biogas to the maximum possible level by diluting natural gas with CO_2. A typical biogas composition with 0.6 CH_4 and 0.4 CO_2 (in mole fraction) was used as reference, and corresponding biogas content in the supplied mixtures was computed. This paper presents the test rig setup used for the experimental activities and reports the results, demonstrating the impact of burning a mixture of biogas and natural gas on the performance and emissions of the MGT. The results indicate that the electrical efficiency is almost unchanged and no significant changes were observed in operating parameters, comparing with the natural gas fired case. It was also shown that burning a mixture of natural gas and biogas contributes to a significant reduction in CO_2 emissions from the plant by about 19% at full load operation. Given the extensive data obtained during the experimental tests, a data-driven model based on an artificial neural network (ANN) was developed to simulate the performance of the MGT. The mean relative error was used to evaluate the prediction accuracy of the developed ANN model with respect to experimental data which were not used during the training. It was demonstrated that the ANN model can predict the performance parameters of the MGT with high accuracy and the error of most samples is less than 1%. A graphical user interface was created for the ANN model in Microsoft Visual Basic. The GUI is presented as a user-friendly tool for modelling and condition monitoring of the plant.

14/03104 Experimental investigation into scaling models of methane hydrate reservoir

Wang, Y. *et al. Applied Energy*, 2014, 115, 47–56.

The cubic hydrate simulator, a three-dimensional 5.8 L cubic pressure vessel, and the pilot-scale hydrate simulator, a three-dimensional 117.8 L pressure vessel, were used for investigating the production processes of hydrate. The gas production behaviours of methane hydrate in the porous media using the thermal stimulation method with a five-spot well system were studied. The experimental conditions were designed by a set of scaling criteria for the gas hydrate reservoir. The experimental results verified that the scaling criteria for gas hydrate production are reliable. The scaling criteria are used for predicting the production behaviour of the real-scale hydrate reservoir. In the model of the real-scale hydrate reservoir with the size of 36 m × 36 m × 36 m, methane of 1.168×10^6 m^3 (STP) was produced from the hydrate reservoir during 13.9 days of gas production. Gas recovery was 0.73, and the final energy efficiency was 9.5.

14/03105 Fractal characteristics of shales from a shale gas reservoir in the Sichuan Basin, China

Yang, F. *et al. Fuel*, 2014, 115, 378–384.

Nanopore structure greatly affects gas adsorption and transport in shales. Such structures in shale samples from the Lower Cambrian strata of the Sichuan Basin of China have been investigated using X-ray diffraction, total organic carbon content (TOC) tests, porosity and permeability tests, nitrogen adsorption and methane adsorption experiments. Fractal dimensions were obtained from the nitrogen adsorption data using the Frenkel–Halsey–Hill method. The relationships between TOC, clay minerals, pore structure parameters and fractal dimension have been investigated. Based on the physical description of the fractal surfaces, the impact of fractal dimension on adsorption capacity has also been discussed. The results showed that the shale samples had fractal geometries with fractal dimensions ranging from 2.68 to 2.83. The organic matter is a controlling factor on fractal dimension, shown by positive correlation between TOC and fractal dimension. Fractal dimension increases with increasing surface area and pore volume, and also increases with decreasing pore diameter because of the complicated pore structure. Micropores have a greater impact on fractal dimension than mesopores and macropores. A negative correlation between fractal dimension and permeability was observed, especially for shales with high TOC and micropores counts. The fractal dimension can be used to evaluate adsorption capacity. Shale samples with larger fractal dimensions have higher methane adsorption capacity. Fractal analysis leads to a better understanding of the pore structure and adsorption capacity of a shale gas reservoir.

14/03106 Gas recovery potential of sandstones from tight gas reservoirs

Duan, Z. *et al. International Journal of Rock Mechanics and Mining Sciences*, 2014, 65, 75–85.

The aim of this study is to characterize experimentally the petrophysical properties of a set of sandstones originating from different depths from a single tight gas field, in order to improve knowledge on their gas recovery potential. The initial characterization of these sandstones is performed in the dry state, and in the 'as received' states: porosity, initial water saturation level and gas permeability at a confining pressure of 5 MPa. For two different samples under increasing confining pressure, the authors have evaluated the water saturation threshold, above which no more gas passes through the porous network, owing to hydraulic cut-off, to be about 63–68%. Then, at intermediate saturation level (of the order of 40%), two different sample types were identified, depending on whether their relative gas permeability is affected, or not, by confining pressure. For one sample of each type, poro-elastic experiments show that the variation in normalized matrix bulk modulus (due to confining pressure increase) may be attributed to the closure of portions of the connected pore network. Finally, to ascertain the above, a dedicated test was designed to measure the pore volume changes under confinement, simultaneously to volumetric strains. Whenever pore volume variation is significantly higher than volumetric strains, pore trapping is identified; otherwise, microstructure changes are mainly attributed to crack closure.

14/03107 Geochemical characteristics of natural gases in the Upper Triassic Xujiahe Formation in the southern Sichuan Basin, SW China

Zecheng, W. *et al. International Journal of Coal Geology*, 2013, 120, 15–23.

The chemical and stable (carbon and hydrogen) compositions of gases in the Upper Triassic Xujiahe Formation (Xujiahe Fm) in the southern Sichuan Basin were analysed and compared with those of gases of the Xujiahe gas pools in other areas of the Sichuan Basin. The geochemical characteristics of the Xujiahe Fm gases in the southern Sichuan Basin are summarized as follows: (a) gases are dominated by alkane gases, and the majority of the natural gas is wet gas. (b) The methylcyclohexane index (I_{MCC6}) and cyclohexane index (I_{CH}) values of the gases are high, indicating that the natural gases originated from humic organic matter. (c) The stable carbon and hydrogen isotopes of methane and its homologues in most of the gases display a normal trend (i.e. $\delta^{13}C_1 < \delta^{13}C_2 < \delta^{13}C_3 < \delta^{13}C_4$), indicating that the gases are primary and have not experienced secondary alteration; a partial reversal of the carbon isotope trend of a few samples is explained by the mixing of gases from the same Xujiahe Fm source rock at different maturity levels. (d) The carbon isotope trends of the C_1–C_4 alkanes are very similar to those of the gases produced in the western and central Sichuan Basin, and the light hydrocarbon composition is similar to that in the central Sichuan Basin; both findings support that the source rocks of the gases in the Xujiahe Fm in the southern Sichuan Basin are coal measures, as in the western and central Sichuan Basin. (e) The

hydrogen isotope values of the alkane gases are higher than those in the western and central Sichuan Basin, indicating a higher salinity of the depositional environment of the Xujiahe Fm in the southern Sichuan Basin. (f) A small part of the natural gas in the Xujiahe Fm in the southern Sichuan Basin is oil-associated gas, which was probably derived from sapropelic source rocks of the Lower Silurian and the Lower Permian.

14/03108 In situ Raman spectroscopic study of diffusion coefficients of methane in liquid water under high pressure and wide temperatures

Guo, H. *et al. Fluid Phase Equilibria*, 2013, 360, 274–278.

Methane is commonly found in sedimentary basins at temperatures of at least 473 K. Accurate values of diffusion coefficients for methane in water at high pressure and elevated temperature are essential to an understanding of transport behaviour of methane in pore spaces at reservoir conditions. However, the experimental data are limited to conditions at low temperatures and pressures. In this study, diffusion coefficients of methane in water were determined under high pressures (up to 40 MPa) and wide temperature range (from 273 to 473 K) via Raman spectroscopic method. The relationship between diffusion coefficient of methane in water [$D(CH_4)$ in m^2/s] and temperature (T in K) was derived with Speedy–Angell power-law approach as: $D(CH_4) = D_0[(T/T_s) - 1]^m$ where $D_0 = 15.95 \times 10^{-9}\,m^2/s$, $T_s = 229.8$ K, $m = 1.8769$. At constant temperature, pressure has very small effect on the diffusion coefficients.

14/03109 Modeling chromatographic separation of produced gas in shale wells

Rezaveisi, M. *et al. International Journal of Coal Geology*, 2014, 121, 110–122.

Field evidence exists showing temporal variation in produced gas composition in shale wells. Preferential gas flow and sorption of the species in shale formations cause compositional variations in the gas produced from shale. This process is similar to gas chromatographic separation, in which the size of gas molecules and their affinity for walls cause separation. As in gas chromatography, shale gas contains molecules of different gases (methane, ethane, propane, carbon dioxide, etc.). When reservoir pressure is greater than critical sorption pressure, sorption process is negligible and the separation process is mainly due to differences in gas molecule speeds in pores. The extremely small size of the pores in shale adds different flow physics, such as Knudsen diffusion and slip flow that intensifies separation of gas components. Understanding and modelling chromatographic separation (CS) in shale can improve knowledge and help to produce more valuable gas from gas shale. The authors have developed a numerical model to study temporal variations of the composition of gas produced from shale gas wells. The model is a physical transport model of single-phase multicomponent gas flow in nanoporous media. The governing equations are implemented into a one-dimensional numerical model and solved using a fully implicit solution method. A sensitivity study of the effect of different parameters such as reservoir pressure, length of the system, tortuosity, and permeability on the CS process is performed. The model results confirm strong CS process in shale. In an early stage of production, the component with the highest Knudsen diffusivity and slip coefficient is produced with a higher mole fraction than its *in situ* composition. At a later time, the same component comprises a smaller mole fraction than its *in situ* composition in the gas production stream. Lower Darcy permeability, a longer system, and higher reservoir pressure intensify the CS process.

14/03110 Modelling of localised gas preferential pathways in claystone

Gerard, P. *et al. International Journal of Rock Mechanics and Mining Sciences*, 2014, 67, 104–114.

A long-term injection gas test on initially saturated claystone samples under isotropic confining pressure is modelled in a two-dimensional hydro-mechanical framework, which includes the hydraulic anisotropy. Evidences of localized pathways through the sample have been observed experimentally, which are difficult to reconcile with standard two-phase flow models. The presence of an embedded pre-existing fracture is included in a continuum finite element model. A hydro-mechanical coupling between the fracture aperture, permeability and the retention properties along the fracture is included in the model. Due to the increase in permeability and the decrease of the air entry pressure induced by the rise in fluid pressure at constant mean total stress, the model provides good agreement with the experimental observations. The discussion offers additional insight into the fluid flow mechanisms into the sample and the processes involved in the development of localized gas pathways. This study allows conclusions to be drawn regarding the performance of the model and its practical limitations.

14/03111 Molecular modeling of the ideal gas enthalpy of formation of hydrocarbons

Borhani, T. N. G. *et al. Fluid Phase Equilibria*, 2013, 360, 423–434.

The ideal gas enthalpy of formation (HFOR) plays a key role in energy balance calculations and the investigation of bond energies, resonance energies and the nature of chemical bonds. Development of accurate structure-based estimation methods for HFOR of a large variety of chemical species can enhance the capability of process and product. In this work, a quantitative structure–property relationship study was performed to simply investigate the HFOR for a diverse DIPPR dataset include 1783 hydrocarbons from 80 diverse chemical classes. Based on the multivariate linear regression (MLR) a multivariate model was developed using robust binary particle swarm optimization (PSO) for the feature selection step. Next, based on the scaled variable reduced coordinates (SVRc), a novel robust mathematical modelling strategy was introduced using PSO that was successfully implemented and checked. The results of the PSO–MLR model and PSO–SVR illustrated that R^2 between predicted and experimental values were 0.9500 and 0.9644, respectively.

14/03112 Quantitative analysis of shales by KBr-FTIR and micro-FTIR

Chen, Y. *et al. Fuel*, 2014, 116, 538–549.

Fine-grained texture, complex mineralogical composition, and diverse organic matter types cause large heterogeneity of shale, and the resulting analytical challenge can only be met with high-resolution techniques. Quantitative determination of clay minerals, quartz and carbonates, as well as organic matter in shale on a micrometre-scale is demonstrated by traditional KBr–Fourier transform infrared (FTIR) spectroscopy and novel reflectance micro-FTIR techniques, respectively, the latter allowing characterization and mapping of areas as small as $20 \times 20\,\mu m^2$. Advantages and limitations of FTIR techniques are discussed mainly with reference to the study of shale, but are relevant also for other fine-grained materials.

14/03113 Stable isotope geochemistry of coal bed and shale gas and related production waters: a review

Golding, S. D. *et al. International Journal of Coal Geology*, 2013, 120, 24–40.

Coal bed and shale gas can be of thermogenic, microbial or of mixed origin with the distinction made primarily on the basis of the molecular and stable isotope compositions of the gases and production waters. Methane, ethane, carbon dioxide and nitrogen are the main constituents of coal bed and shale gases, with a general lack of C_{2+} hydrocarbon species in gases produced from shallow levels and more mature coals and shales. Evidence for the presence of microbial gas include $\delta^{13}C$–CH_4 values less than -50‰, covariation of the isotope compositions of gases and production water, carbon and hydrogen isotope fractionations consistent with microbial processes, and positive $\delta^{13}C$ values of dissolved inorganic carbon in production waters. The CO_2-reduction pathway is distinguished from acetate/methyl-type fermentation by somewhat lower $\delta^{13}C$–CH_4 and higher δD–CH_4, but can also have overlapping values depending on the openness of the microbial system and the extent of substrate depletion. Cross-plots of $\delta^{13}C$–CH_4 versus $\delta^{13}C$–CO_2 and δD–CH_4 versus $\delta^{13}C$–H_2O may provide a better indication of the origin of the gases and the dominant metabolic pathway than the absolute carbon and hydrogen isotope compositions of methane. In the majority of cases, microbial coal bed and shale gases have carbon and hydrogen isotope fractionations close to those expected for CO_2 reduction. Primary thermogenic gases have $\delta^{13}C$–CH_4 values greater than -50‰, and $\delta^{13}C$ values that systematically increase from C_1 to C_4 and define a relatively straight line when plotted against reciprocal carbon number. Although coals and disseminated organic matter in shales represent a continuum as hydrocarbon source rocks, current data suggest a divergence between these two rock types at the high maturity end. In deep basin shale gas, reversals or rollovers in molecular and isotopic compositions are increasingly reported in what is effectively a closed shale system as opposed to the relative openness in coal measure environments. Detailed geochemical studies of coal bed and shale gas and related production waters are essential to determine not only gas origins but also the dominant methanogenic pathway in the case of microbial gases.

14/03114 Study on combustion and ignition characteristics of natural gas components in a micro flow reactor with a controlled temperature profile

Kamada, T. *et al. Combustion and Flame*, 2014, 161, (1), 37–48.

Combustion and ignition characteristics of natural gas components such as methane, ethane, propane and *n*-butane were investigated experimentally and computationally using a micro flow reactor with a controlled temperature profile. Special attention was paid to weak flames which were observed in a low flow velocity region. The observed weak flame responses for the above fuels were successfully simulated by one-dimensional computations with a detailed kinetic model for natural gas. Since the position of the weak flame indicates the ignition characteristics as well as the reactivity of each fuel, the experimental and computational results were compared with research octane number

(RON) which is a general index for ignition characteristics of ordinary fuels. At 1 atm, ethane showed the highest reactivity among these fuels, although RON of ethane (115) is between those of methane (120) and propane (112). Since the pressure conditions are different between the present experiment and the general RON test, weak flame responses to the pressure were investigated computationally for these fuels. The order of the fuel reactivity by the reactor agreed with that by RON test when the pressure was higher than 4 atm. Reaction path analysis was carried out to clarify the reasons of the highest reactivity of ethane at 1 atm among the employed fuels in this study. The analysis revealed that $C_2H_5 + O_2 \rightleftharpoons C_2H_4 + HO_2$ is a key reaction and promotes ethane oxidation at 1 atm. The effect of the pressure on the fuel oxidation process in the present reactor was also clarified by the analysis. In addition, weak flame responses to various mixing ratios of methane/*n*-butane blends were investigated experimentally and computationally. The results indicated a significant effect of *n*-butane addition in the blends on combustion and ignition characteristics of the blended fuels.

Transport, storage

14/03115 Methane and carbon dioxide adsorption in clay-like slit pores by Monte Carlo simulations

Jin, Z. and Firoozabadi, A. *Fluid Phase Equilibria*, 2013, 360, 456–465.

Shale is composed of two distinct permeable media: inorganic and organic. Both media may contribute to the amount of hydrocarbon and non-hydrocarbon species in shale. This study investigates sorption in clay minerals which may constitute most of the inorganic matter in shale. The inorganic matter is represented by the montmorillonite clays with different charges for different atoms. Sorption of methane and carbon dioxide is investigated by Monte Carlo simulations. In this work, it is assumed that methane is structureless and CO_2 is assumed to have structure and partial charges to its atoms are assigned. The results indicate that charge affects the orientation of CO_2 molecules close to the surface and plays an important role in CO_2 sorption. Methane sorption is found to be mainly a function of surface area. The authors also incorporate cation exchange in clay description and model its effect on sorption. Cation exchange increases CO_2 sorption at low pressure significantly and as pressure increases, the effect becomes less pronounced. Cation exchange also affects orientation of CO_2 molecules near the surface. Results from the simulation are expected to provide insight into phase behaviour in clays, a major constituent of shale media.

14/03116 Nonlinear finite element analysis of collapse and post-collapse behaviour in dented submarine pipelines

Ramasamy, R. and Tuan Ya, T. M. Y. S. *Applied Ocean Research*, 2014, 46, 116–123.

The venture of oil and gas exploration into deeper waters has increased significantly in these recent years, as the shallow water fields approaching exhaustion. Large diameter pipelines installed in these areas are exposed to the severe pressure loading resulting from the water depth and any pre-installation damages sustained during transportation or pipelay and may reduce the collapse and buckle propagation resistance drastically. This work focuses on the utilization and application of the finite element method as a robust and practical engineering tool to establish a methodology for analysing the effects of initial imperfections in the form of dents of various shapes and sizes on pipelines, sustained prior to pipelay, to determine the collapse pressure and buckle propagation pressure which can result in costly abandonments and unnecessary replacements. Comparison between the available theoretical closed-form simplified solutions available via two-dimensional ring analogy, the experimental test conducted by various researchers on steel tubes, empirical formulations from past works and the analysis results obtained from this research were conducted, by incorporating the material plasticity, residual stresses and external pressure. The methodology employed here provides a relatively realistic and practical assessment tool for computing the collapse and buckle propagation pressures of dented large-diameter submarine pipelines.

14/03117 Simulation of gas desorption and geomechanics effects for unconventional gas reservoirs

Yu, W. and Sepehrnoori, K. *Fuel*, 2014, 116, 455–464.

Hydraulic fracturing of horizontal wells is crucial for economic production of shale gas. Impacts of gas desorption and geomechanics in hydraulic fractures on ultimate gas recovery are not clearly understood and systematically investigated. In this paper, the authors perform history matching with two field gas production data from Barnett Shale and Marcellus Shale, and first analyse the positive contribution of gas desorption and the negative effect of geomechanics on gas production, respectively, and then compare these two effects on gas production with the purpose of identifying which effect is dominant in the whole process of gas production. Furthermore, the authors numerically study the effect of gas desorption on gas recovery with available laboratory data of Langmuir isotherm from five different shale formations including Barnett Shale, New Albany Shale, Eagleford Shale, Marcellus Shale and Haynesville Shale. The method of design of experiment is used to perform sensitivity studies with six uncertain parameters such as reservoir permeability, bottom hole pressure, fracture conductivity, initial reservoir pressure, porosity, and fracture spacing to screen insignificant parameters and obtain critical parameters that control this process. This paper enables operators to develop an early better understanding of the effects of gas desorption and geomechanics on shale gas well performance, and provides insights into history matching and optimization of hydraulic fracturing treatment design for shale gas production.

14/03118 Steady current induced vibration of near-bed piggyback pipelines: configuration effects on VIV suppression

Zang, Z.-P. and Gao, F.-P. *Applied Ocean Research*, 2014, 46, 62–69.

A series of experiments on steady current-induced vibration of piggyback pipelines close to a plane seabed were conducted with a hydro-elastic facility in a conventional water flume. The effects of the mass-damping parameter, the diameter ratio, the gap-to-diameter ratio, the spacing-to-diameter ratio and the position angle on the vortex-induced vibration (VIV) response were studied. The VIV suppression for the piggyback pipeline system by the small pipe was investigated based on the analysis of the vibration amplitude and the critical reduced velocity for the onset of VIV. Comparison with the prediction with the modified Griffin plot in an earlier study, shows that the peak vibration amplitude of near-wall piggyback pipelines is smaller than that for a wall-free single pipe. The configuration parameters of piggyback pipelines have significant effects on the VIV suppression. For the configuration of the small pipe above the main pipe ($\theta = 90°$), the minimum peak amplitude and the maximum critical reduced velocity occur at the spacing-to-diameter ratio of $G/D \approx 0.25$, indicating that VIV is suppressed most effectively by the small pipe at this value of G/D. For a constant value of $G/D = 0.25$, both the minimum peak amplitude and the maximum critical reduced velocity occur at the position angle of $\theta \approx 120°$.

14/03119 The use of alternating conditional expectation to predict methane sorption capacity on coal

Feng, Q. *et al. International Journal of Coal Geology*, 2014, 121, 137–147.

Conventional approaches to determine methane sorption capacity, including manometric, volumetric and gravimetric methods, require complex procedure of preparation of coal samples and long-term sorption measurement. This article proposed the use of alternating conditional expectation (ACE) algorithm to relate methane sorption capacity (V_L) to coal composition, vitrinite reflectance and temperature without conducting sorption tests, which minimizes the work volume and time required in conventional measurement method. The basic idea behind the ACE is to estimate a suit of optimal transforms of a dependent and a set of independent variables that result in a linear correlation between the transformed independent and dependent variables with minimum error. Underlying effect can be uncovered of the control of each independent variable on dependent variable through the transform. One hundred and thirty-nine sets of proximate analysis, maceral analysis and methane sorption data from previous studies were acquired. Ash, fixed carbon, moisture, vitrinite content, vitrinite reflectance and temperature were selected as independent variables to predict V_L. The resulted ACE transforms have a correlation coefficient R^2 of 0.91, indicating an excellent match between the predicted and measured V_L values. Normality and homoscedasticity were verified by Lilliefors- and F-test, which further confirmed the capability of ACE as being a correlation tool. The effects of independent variables on V_L observed from the transforms show an agreement with previous studies. Based on the ACE transform results, an explicit V_L model was proposed bearing a polynomial correlation with the independent variables. The validity of the proposed model was proved by fitting it to another 43 data sets. Additionally, outlier diagnose was conducted through standardized residuals and their effect on prediction accuracy was investigated.

14/03120 Upgrading landfill gas using a high pressure water absorption process

Rasi, S. *et al. Fuel*, 2014, 115, 539–543.

The upgrading of landfill gas (methane $54.2 \pm 2.0\%$, carbon dioxide $42.1 \pm 2.4\%$ and nitrogen $3.7 \pm 1.2\%$) was studied with a pilot-scale high pressure water absorption system consisting of absorption, desorption and gas drying units. The gas was upgraded in two phases and with two absorption columns operating in sequence in pressures up to 180 bar, and with initial pressures of 8 and 10 bar. This type of high pressure process, where water is used for increasing the gas pressure,

does not need a separate compression unit to produce the gas pressure required by gas vehicles. Product gas with a methane contents ranging from 83.0% to 92.1% was achieved with differing process parameters, the carbon dioxide and nitrogen content of the product gas ranged from 4.4% to 6.3% and 2.5% to 7.4%, respectively. Hydrogen sulfide was removed from the raw landfill gas with over 99% efficiency. To conclude the used high pressure gas absorption technique is capable for upgrading landfill gas to $87.9 \pm 2.0\%$ methane content.

Economics, business, marketing, policy

14/03121 Energy poverty reduction by fuel switching. Impact evaluation of the LPG conversion program in Indonesia

Andadari, R. K. *et al. Energy Policy*, 2014, 66, 436–449.

In low- and middle-income countries, liquefied petroleum gas (LPG) can be an attractive alternative to the widespread use of traditional kerosene. Not only is LPG a relatively clean, safe and cost-effective fuel for households, its large-scale adoption also reduces the heavy burden of kerosene consumption subsidies on government budgets. Against this background, the authors evaluate the impact of a large government programme to substitute LPG for kerosene in Indonesia. Using a household survey across urban, suburban and rural regions, it was found that this programme was very effective in causing a large-scale shift from kerosene to LPG. This shift was positively influenced by level of education, household size and household income. Contradicting the energy-ladder model, the LPG programme, reinforced by an increase in the price of kerosene, led to increased stacking of fuels, including increasing consumption of both electricity and traditional biomass. In addition, this analysis shows that the LPG programme failed to substantially reduce the overall number of energy-poor people, but it has been effective in alleviating extreme energy-poverty. Finally, it was found that medium and higher income households in suburban areas benefitted most from the LPG programme.

14/03122 Strategic Eurasian natural gas market model for energy security and policy analysis: formulation and application to South Stream

Chyong, C. K. and Hobbs, B. F. *Energy Economics*, 2014, 44, 198–211.

The mathematical formulation of a strategic Eurasian natural gas market model is presented. The model represents horizontal oligopolistic relationships among producers, bilateral market power between producer (Russia) and transit (Ukraine) countries, detailed transport constraints, and operation decisions over a 20-year time horizon. To demonstrate the model's capabilities, a financial and market analysis of the proposed South Stream gas pipeline from Russia via the Black Sea to southern Europe is summarized. Insights obtained include the following. First, expectations of high demand growth in Europe and/or transit risks do not justify the construction of the South Stream pipeline because under all demand and Ukraine transit interruption scenarios, the net benefits to the South Stream participants are negative [the net present value (NPV) ranges from −$1.9 billion to −$7.4 billion]. Second, Ukraine's perception of high transit market power *vis-à-vis* Russia may trigger the construction of the otherwise unprofitable South Stream project. Thus, under Ukraine's high transit market power scenario, the NPV of South Stream ranges between $2.4 billion and $24.5 billion. Third, it was found that the South Stream investment increases the efficiency of the European gas market under the following conditions: (i) when gas demand in Europe grows 2% per year up to 2030, (ii) when Ukraine poses high transit market power or (iii) under a combination of severe transit risks through Ukraine and low demand scenarios in Europe. It should be noted that the value of South Stream to both its project sponsors and the market as a whole is much higher when Ukraine exercises transit market power than under the high demand scenario. Therefore, whether Ukraine is likely to wield market power is crucial to the success of the South Stream project because that is the only scenario in which the project yields both a positive expected NPV to its sponsors and the highest value to the market as a whole.

Derived gaseous fuels

14/03123 A two dimensional Euler–Lagrangian model of wood gasification in a charcoal bed – part I: model description and base scenario

Gerber, S. and Oevermann, M. *Fuel*, 2014, 115, 385–400.

This article presents a parameter study for a Euler–Lagrangian model with an application to wood gasification in fluidized beds. The bed material consists of charcoal and wood only. The detailed model involves processes of heat up, drying, particle shrinkage, primary and secondary pyrolysis, gasification, and tar decomposition. Initially, they introduce a bidisperse mixture of 12,000 charcoal particles idealized as perfect spheres. The collision model is based on a linear discrete element method and allows to account for multiple particle–particle contacts and collisions. This first part of the study gives a detailed description of the model with all submodels and assumptions. The base scenario mimics experimental conditions of a laboratory-scale fluidized bed reactor. The base scenario will be used in the second part of the study as the base of comparison for a comprehensive parameter study. The data shown for the base scenario include temporal data for the reactor outlet temperature and species concentrations (including tars) as well as barycentre data for the solid phases. The data gained from the simulation are also compared to available experimental data.

14/03124 An efficient multi criteria process optimization framework: sustainable improvement of the dimethyl ether process

Shokrian, M. and High, K. A. *Computers & Chemical Engineering*, 2014, 60, 213–230.

No longer is it appropriate to evaluate processes for economic feasibility alone; social benefits and environmental impacts must also be considered. This work develops a multi-criteria systematic framework for optimum process design with sustainability considerations and addresses a major challenge in process design as engineers will now be able to design for multiple criteria, specifically sustainability concerns. A novel multi-objective optimization algorithm capable of handling a multitude of objectives in mixed integer non-linear search space and a novel decision-making methodology are integrated with a sequential modular process simulator to optimize processes with a multitude of objectives rigorously and efficiently. The application of this research extends well beyond sustainability considerations to the very vast area of optimum design with multi-criteria. The application of the proposed framework is demonstrated through a case study for process retrofit of dimethyl ether production plant.

14/03125 CO-hydrogenation of syngas to fuel using silica supported Fe–Cu–K catalysts: effects of active components

Das, S. K. *et al. Fuel Processing Technology*, 2014, 118, 82–89.

Fe–Cu–K/SiO_2 catalysts prepared by varying the amount of active components have been investigated to explain the effects of active components on the activity, selectivity, product carbon number distribution, and nature of coke formation during Fischer–Tropsch synthesis. The catalysts were prepared by co-precipitation technique using silica as support, followed by adding K promoters by wet impregnation technique. Active component composition, textural properties, metal dispersion and acidity of the catalysts were determined. Further surface morphology, structural characteristics and structural changes occurred during the course of Fischer–Tropsch synthesis were studied. Fischer–Tropsch synthesis has been investigated in a fixed bed micro-reactor with *in situ* reduction of catalysts, using H_2 as a reducing agent. The identification of different key components present in liquid products formed was done by gas chromatography–mass spectrometry. The spent catalyst was also characterized to understand the catalyst deactivation. The results have been discussed in relation to the loading of active components on catalysts and their influence on the textural and morphological properties, structural characteristics, as well as catalytic activity, selectivity towards product distribution and properties and nature of coke formation.

14/03126 Effect of steam injection location on syngas obtained from an air–steam gasifier

Sharma, A. M. *et al. Fuel*, 2014, 116, 388–394.

For a fluidized-bed gasifier, reaction conditions vary along the height of the reactor. Hence, the steam injection location may have a considerable effect on the syngas quality. The objective of this study was to investigate the effects of steam injection location and steam-to-biomass ratio (SBR) on the syngas quality generated from an air–steam gasification of switchgrass in a 2–5 kg/h autothermal fluidized-bed gasifier. Steam injection locations of 51, 152 and 254 mm above the distributor plate and SBRs of 0.1, 0.2 and 0.3 were selected. Results showed that the syngas H_2 and CO yields were significantly influenced by the steam injection location ($p < 0.01$) and SBR ($p < 0.05$). The steam injection location also significantly influenced hot and cold gas, as well as carbon conversion efficiencies. The best syngas yields (0.018 kg H_2/kg biomass and 0.513 kg CO/kg biomass) and gasifier efficiencies (cold gas efficiency of 67%, hot gas efficiency of 72%, and carbon conversion efficiency of 96%) were at the steam injection location of 254 mm and SBR of 0.2.

14/03127 Fate of inorganic matter in entrained-flow slagging gasifiers: fuel characterization

Duchesne, M. A. *et al. Fuel Processing Technology*, 2014, 118, 208–217.
This study is the first of a three-part research programme which involves fuel characterization, testing in a 1 MW_{th} gasifier, and computational fluid dynamics (CFD) modelling for entrained-flow slagging gasification. Focus is on the behaviour of inorganic fuel components since the end goal is to develop a CFD model which includes inorganic matter transformations. Initially, four coals were selected for this programme and one limestone was also chosen to act as a fluxing agent. Fuel properties related to ash particle formation, gas-particle transport, particle sticking, slag flow and slag-refractory interaction are provided with prioritization based on their potential application for screening of potential fuels, ensuring proper gasifier operation, gasifier design and/or CFD modelling. The selection of one or multiple experimental and/or modelling techniques is justified and applied to determine each relevant property. Of the four coals tested, one was deemed unsuitable based on initial screening tests. Two of the three remaining coals require fluxing for proper gasifier operation. Design tests showed that alumina is preferred over silicon carbide and alumina–chromia (with 30 wt% chromia) for use as refractory material with the selected fuels. Characterization for CFD modelling is also discussed with results provided as supplementary data.

14/03128 Glucose gasification in near critical water conditions for both syngas production and green chemicals with a continuous process

Molino, A. *et al. Fuel*, 2014, 115, 41–45.
This paper reports experiments on glucose gasification with water at near critical point. The adoption of these process conditions revealed advantages in terms of biomass conversion efficiency as the resulting liquid phase includes some important compounds (HFM, furfural). Three phases were produced, collected and then analysed: solid (23% w/w), liquid (70%) and gas (7%). The predominance of the non-gaseous phase can be attributed to the fact that operational condition are near the water critical point instead of effective supercritical conditions. Composition data are an average value of three repetitions and mass balance rules were verified in all runs and a good agreement was found with open literature data. The solid residual in the reaction chamber was added to that suspended in the liquid fraction and the obtained mass was dried ($T = 105\,^{\circ}C$) and resulting in about 90 g with 50% moisture content. Also the effect of NaOH, active in gasification reactions was investigated. Results revealed a good impact in liquid yield and composition, while carbon dioxide amount increased in the resulting gas phase. A reaction scheme is also proposed to justify these experimental evidences.

14/03129 Pilot verification of a low-tar two-stage coal gasification process with a fluidized bed pyrolyzer and fixed bed gasifier

Zeng, X. *et al. Applied Energy*, 2014, 115, 9–16.
A 50 kg/h autothermal two-stage gasifier, consisting of a fluidized bed (FB) pyrolyser and a downdraft fixed-bed gasifier, has been designed and built according to previous laboratory researches. In the experiments, lignite gasification was performed in this innovative two-stage gasifier to demonstrate the process feasibility for clean fuel gas production. The results showed that when keeping the reaction temperatures of the FB pyrolyser and downdraft fixed bed gasifier respectively at about 860 and 1100 °C, the tar content in the produced fuel gas from the two-stage gasifier was effectively lowered to 84 mg/$N\,m^3$ and the heating value of fuel gas was close to 4.186 MJ/$N\,m^3$. Compared with the tar produced in the FB pyrolyser, the tar from the downdraft fixed bed gasifier had obviously higher content of light oil components and lower content of heavy components, showing essentially an effective catalytic reforming of tar components by the hot char bed of the downdraft fixed bed gasifier.

14/03130 Solar thermal reforming of methane feedstocks for hydrogen and syngas production – a review

Agrafiotis, C. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 656–682.
It is currently accepted that at least for a transition period, solar-aided reforming of methane-containing gaseous feedstocks with natural gas being the first choice, can offer a viable route for fossil fuel decarbonization and create a transition path towards a 'solar hydrogen–solar fuels' economy. Both industrially established traditional reforming concepts, steam and dry/carbon dioxide reforming, being highly endothermic can be rendered solar-aided and thus offer in principle a real possibility to lower the cost for introducing renewable hydrogen production technologies to the market by a combination of fossil fuels and solar energy. They also share similar technical issues considering linking of their key thermochemistry and thermodynamics to efficient exploitation of solar energy. In this perspective, this paper presents the development and current status of solar-aided reforming of gaseous methane-containing feedstocks, focusing in particular on the reactor technologies and concepts employed so far to couple the heat requirements of the methane reforming process to the underlying principles, intricacies and peculiarities of concentrated solar power exploitation. A literature review is presented, addressing practically the whole scale of solar reactors employed so far: from small-scale reactor prototypes often tested under simulated solar irradiation up to scaled-up reformer reactors tested on solar platform sites at the level of few hundreds of kilowatts. Having presented the current state of the art of the technology, topics for future work are suggested and issues to help further commercialization are addressed.

14/03131 Study on an iron–nickel bimetallic Fischer–Tropsch synthesis catalyst

Li, T. *et al. Fuel Processing Technology*, 2014, 118, 117–124.
A systematic study was undertaken to investigate the effects of the addition of nickel on the bulk phase composition and reduction/carburization behaviours of a Fe–Ni bimetallic catalyst. The catalyst samples were characterized by powder X-ray diffraction, transmission electron microscopy, Mössbauer spectroscopy, X-ray photoelectron spectroscopy and H_2 (or CO) temperature-programmed reduction. The Fischer–Tropsch synthesis performance of the catalysts was measured at 1.5 MPa, 250 °C and syngas with H_2/CO ratio of 2.0. The characterization results indicated that the fresh nickel-promoted catalysts are mainly composed of α-Fe_2O_3 and $NiFe_2O_4$. The addition of nickel improves the dispersion of iron oxides and decreases the crystallite size of metal oxides. The presence of nickel increases the rates of reduction and carburization in H_2 and CO, respectively, while suppresses the formation of the iron carbides in the syngas reduction. The incorporation of nickel improves the selectivity to methane and suppresses the formation of heavy hydrocarbons (C_{5+}). The catalyst with high nickel content has a high selectivity to methane and low selectivity to heavy hydrocarbons (C_{5+}).

LNG

14/03132 A combined cycle utilizing LNG and low-temperature solar energy

Rao, W.-J. *et al. Applied Thermal Engineering*, 2013, 60, (1–2), 51–60.
This paper has proposed a combined cycle, in which low-temperature solar energy and cold energy of liquefied natural gas (LNG) can be effectively utilized together. Comparative analysis based on a same net work output between the proposed combined cycle and separated solar organic Rankine cycle and LNG vapour system has been done. The results show that, for the combined cycle, a decrease of nearly 82.2% on the area of solar collector is obtained and the area of heat exchanger decreases by 31.7%. Moreover, exergy efficiency is higher than both two separated systems. This work has also dealt with the thermodynamic analyses for the proposed cycle. The results show that R143a followed by propane and propene emerges as most suitable fluid. Moreover, with a regenerator added in the cycle, performance improvement is obtained for the reduction on area of solar collector and increase on system efficiency and exergy efficiency.

14/03133 A novel process for small-scale pipeline natural gas liquefaction

He, T. B. and Ju, Y. L. *Applied Energy*, 2014, 115, 17–24.
A novel process for small-scale pipeline natural gas liquefaction is designed and presented. The novel process can utilize the pressure exergy of the pipeline to liquefy a part of natural gas without any energy consumption. The thermodynamic analysis including mass, energy balance and exergy analysis are adopted in this paper. The liquefaction rate and exergy utilization rate are chosen as the objective functions. Several key parameters are optimized to approach the maximum liquefaction rate and exergy utilization rate. The optimization results showed that the maximum liquefaction rate is 12.61% and the maximum exergy utilization rate is 0.1961. What is more, the economic performances of the process are also discussed and compared by using the maximum liquefaction rate and exergy utilization rate as indexes. In conclusion, the novel process is suitable for pressure exergy utilization due to its simplicity, zero energy consumption and short payback period.

14/03134 Novel combined cycle configurations for propane pre-cooled mixed refrigerant (APCI) natural gas liquefaction cycle

Mortazavi, A. *et al. Applied Energy*, 2014, 117, 76–86.
A significant amount of energy is required for natural gas liquefaction. Due to the production scale of liquefied natural gas (LNG) plants, they consume an intensive amount of energy. Consequently, any enhancement to the energy efficiency of LNG plants will result in a considerable reduction in natural gas consumption and CO_2 emission.

Compressor drivers are the main energy consumer in the LNG plants. In this paper, 14 different driver cycle enhancement options were considered. A number of these options have not been proposed for the LNG plants. The new driver cycle development was performed by analysing and optimizing the design variables of four conventional driver cycle enhancement options. The optimization results were used to develop more efficient cycles through mitigating the active constrains and driver cycle innovations. Based on the current available technologies five of these newly developed driver cycle configurations have higher efficiency than the most efficient existing conventional driver cycle. The best-developed driver cycle enhancement option improved the base driver cycle energy efficiency by 38%. The effects of technological advancement on the performances of the all driver cycle enhancement options were also considered.

14/03135 On enhancement of incompressible SPH method for simulation of violent sloshing flows

Gotoh, H. *et al. Applied Ocean Research*, 2014, 46, 104–115.

This paper presents two schemes for enhancement of incompressible smoothed particle hydrodynamics (SPH)-based methods in the simulation of violent sloshing flows, and in particular, sloshing-induced impact pressures. The enhanced schemes include a higher order Laplacian (HL) and an error-compensating source (ECS) of Poisson pressure equation. These two schemes correspond to those derived within the framework of moving particle semi-implicit method and are proposed for the first time within the framework of SPH. The enhancing effects of HL and ECS schemes are shown by simulating violent sloshing flows induced by sway excitations and rotational ones. The significance of dynamically adjusted coefficients in the ECS-related schemes is highlighted by considering a previously applied scheme comprising of a constant coefficient and a corresponding newly proposed one which incorporates a dynamic coefficient. Concise insights are presented on appropriate choice of kernel function.

14/03136 Optimization and analysis of mixed refrigerant composition for the PRICO natural gas liquefaction process

Xu, X. *et al. Cryogenics*, 2014, 59, 60–69.

In this paper, the energy optimization of the PRICO natural gas liquefaction process was performed with the genetic algorithm and the process simulation software Aspen Plus. Then the characteristics of the heat transfer composite curves of the cold box were obtained and analysed. Based on it, the heat exchange process in the cold box was divided into three regions. Finally, in order to find the relationship between the energy consumption and the composition of the mixed refrigerant, the effects of the refrigerant flow composition on the temperature difference and the pinch point location were deeply investigated, which would be useful to guide the refrigerant charging.

14/03137 Two-phase heat transfer and pressure drop of LNG during saturated flow boiling in a horizontal tube

Chen, D. and Shi, Y. *Cryogenics*, 2013, 58, 45–54.

Two-phase heat transfer and pressure drop of liquefied natural gas (LNG) have been measured in a horizontal smooth tube with an inner diameter of 8 mm. The experiments were conducted at inlet pressures from 0.3 to 0.7 MPa with a heat flux of 8–36 $kW\,m^{-2}$, and mass flux of 49.2–201.8 $kg\,m^{-2}\,s^{-1}$. The effect of vapour quality, inlet pressure, heat flux and mass flux on the heat transfer characteristic are discussed. The comparisons of the experimental data with the predicted value by existing correlations are analysed. Four frictional pressure drop methods are also chosen to compare with the experimental database.

Hydrogen generation and storage

14/03138 Alkali-activated blast furnace slag-based nanomaterial as a novel catalyst for synthesis of hydrogen fuel

Zhang, Y. J. and Chai, Q. *Fuel*, 2014, 115, 84–87.

Alkali-activated granulated blast furnace slag-based cementitious material (AGBFSCM) was synthesized and was firstly used as a novel catalyst for synthesis of hydrogen fuel by photocatalytic decomposition of water. X-ray diffraction and field emission scanning electron microscope results indicated that there are two kinds of principally mineralogical phases of calcium silicate hydrate and calcium aluminate hydrate with mean particle size about 50 nm. The AGBFSCM specimen showed excellent H_2 evolution in amount of 51,697 μmol/g under the irradiation of solar simulation source for 6 h due to the synergistic effect of mesoporous AGBFSCM framework and natural oxide semiconductors of Fe_2O_3 and TiO_2 existed in AGBFSCM matrix.

14/03139 Comparison of the performance of compressed-air and hydrogen energy storage systems: Karpathos island case study

Karellas, S. and Tzouganatos, N. *Renewable and Sustainable Energy Reviews*, 2014, 29, 865–882.

Two diverse energy storage technologies, namely the compressed-air and hydrogen energy, are examined. In particular, a steady-state analysis (IPSEpro simulation software) of four configurations of micro-compressed air energy storage (CAES) systems is conducted from the energetic and exergetic point of view. The hydrogen energy storage system is dynamically simulated using HOMER energy software. Load and wind profiles for the island of Karpathos are used as input data to the program. The two-stage micro-CAES system without air preheating is selected to be investigated dynamically as it is proven to have high efficiency and zero emissions. The final part of the paper compares the two systems in terms of energy storage efficiency, including an approximation of the costs and highlights the technological advantages and disadvantages of these technologies.

14/03140 Large enhancements in hydrogen production of TiO_2 through a simple carbon decoration

Chao, K.-J. *et al. Carbon*, 2013, 62, 69–75.

A simple carbon decoration, involving only immersion in adipic acid followed by calcination in N_2 atmosphere, was developed to prepare thin carbon layer decorated TiO_2 nanoparticles. The thin carbon layer was in tight contact with the TiO_2 domain and served as an electron trapping centre to improve charge separations necessary for enhancement in photocatalytic water splitting performance of the TiO_2 nanoparticles. With an optimal carbon loading of 0.3 wt%, a four-fold improvement was achieved for hydrogen production as compared with that achieved by pristine TiO_2 nanoparticles. This simple carbon decoration provides a promising low-cost alternative to traditional Pt-decoration approaches for enhancing hydrogen productions from photocatalytic water splitting.

14/03141 Methanol steam reforming for hydrogen generation via conventional and membrane reactors: a review

Iulianelli, A. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 355–368.

In recent years, hydrogen has gained considerable attention as an energy carrier useful for various applications and, particularly, for polymer electrolyte membrane fuel cells (PEMFCs). Nevertheless, PEMFCs require highly pure hydrogen as a feeding fuel, which shows some limitations regarding storage and transportation. Therefore, to overcome these problems, the *in situ* hydrogen generation has made both the alcohols and hydrocarbons steam-reforming reaction attractive. Among other fuels, methanol is an interesting hydrogen source because it is liquid at ambient conditions, possesses relatively high H/C ratio, low reforming temperature (200–300 °C) and it is also producible from biomass. Meanwhile, there is a comprehensive literature about inorganic membrane reactors utilization for hydrogen generation via the methanol steam reforming reaction. This review illustrates the earlier state of the art from an experimental point of view about hydrogen production from methanol reforming performed in both conventional and membrane reactors. Furthermore, a short overview about methanol reforming catalysts as well as a discussion on the impact of methanol steam reforming process via inorganic membrane reactors to produce hydrogen for PEMFCs supply is given.

14/03142 Optimization of hydrogen production in in-situ catalytic adsorption (ICA) steam gasification based on response surface methodology

Yusup, S. *et al. Biomass and Bioenergy*, 2014, 60, 98–107.

This study investigates the optimization of hydrogen (H_2) production with *in situ* catalytic adsorption (ICA) steam gasification by using a pilot-scale fluidized bed gasifier. Two important response variables, i.e. H_2 composition (in percentage volume fraction) and H_2 yield (in $g\,kg^{-1}$ of biomass) are optimized with respect to five process variables such as temperature (600–750 °C), steam-to-biomass mass ratio (1.5–2.5), adsorbent-to-biomass mass ratio (0.5–1.5), superficial velocity (0.15–0.26 $m\,s^{-1}$) and biomass particle size (350 μm to 2 mm). The optimization study is carried out based on response surface methodology (RSM) using central composite rotatable design (CCRD) approach. The adsorbent-to-biomass mass ratio is found to be the most significant process variables that influenced the H_2 composition, whereas temperature and biomass particle size are found to be marginally significant. For H_2 yield, temperature is the most significant process variables followed by steam-to-biomass mass ratio, adsorbent-to-biomass mass ratio and biomass particle size. The optimum process conditions are found to be at 675 °C, steam-to-biomass mass ratio of 2.0, adsorbent-to-biomass mass ratio of 1.0, superficial velocity of 0.21 $m\,s^{-1}$ that is equivalent to four times the minimum fluidization

velocity, and 1.0–2.0 mm of biomass particle size. The theoretical response variables predicted by the developed model fit well with the experimental results.

14/03143 Synthesis and hydrogen storage properties of Mg–10.6La–3.5Ni nanoparticles

Liu, T. *et al. Journal of Power Sources*, 2014, 246, 277–282.

The Mg–10.6 wt% La–3.5 wt% Ni nanoparticles are prepared by hydrogen plasma-metal reaction method. These nanoparticles are made of Mg, LaH_3 and a small amount of Mg_2Ni. The as-prepared Mg nanoparticles of 180 nm are single crystalline and quasi-spherical in shape, and they change into polycrystalline after activation. LaH_3 and Mg_2Ni nanoparticles are nearly spherical in shape with the mean particle size of 15 nm, and disperse on the surface of Mg. The Mg–10.6La–3.5Ni nanoparticles can absorb 3.2 wt% H_2 in less than 15 min at 523 K and accomplish a high hydrogen storage capacity of 6.5 wt% H_2 in less than 10 min at 673 K, almost reaching the theoretical gravimetric capacity. They can release 4.2 wt% H_2 in 3 min at 623 K. The synergistic catalytic effect of LaH_3 and Mg_2Ni nanoparticles, the nanostructure and the low oxide content of Mg nanoparticles promote the hydrogen sorption process with the low hydrogen absorption activation energy of 39.1 kJ mol^{-1}.

14/03144 The intensification technologies to water electrolysis for hydrogen production – a review

Wang, M. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 573–588.

Water electrolysis derived by renewable energy such as solar energy and wind energy is a sustainable method for hydrogen production due to high purity, simple and green process. One of the challenges is to reduce energy consumption of water electrolysis for large-scale application in the future. Cell voltage, an important criterion of energy consumption, consists of theoretical decomposition voltage (U^{θ}), ohmic voltage drop ($i^{*}\Sigma R$) and reaction overpotential (η). The kinetic and thermodynamic roots of high cell voltage are analysed systemically in this review. During water electrolysis, bubble coverage on electrode surface and bubble dispersion in electrolyte, namely the bubble effect, result in high ohmic voltage drop and large reaction overpotential. Bubble effect is one of the key factors for high energy consumption. Based on the theoretical analysis, recent intensification technologies of water electrolysis are divided into three categories: external field, new electrolyte composition and new thermodynamic reaction system. The fundamentals and development of these intensification technologies are discussed and reviewed. Reaction overpotential and ohmic voltage drop are improved kinetically by external field or new electrolyte composition. The thermodynamic decomposition voltage of water is also reduced by new reaction systems such as solid oxide electrolysis cell and carbon-assisted water electrolysis.

14/03145 Thermophilic biohydrogen production using pre-treated algal biomass as substrate

Roy, S. *et al. Biomass and Bioenergy*, 2014, 61, 157–166.

Algal biomass is rich in carbohydrates which can be utilized as a promising source of substrate for dark fermentation. It becomes more significant when biomass is produced by capturing atmospheric greenhouse gas, CO_2. In the present study, clean energy was generated in the form of biohydrogen utilizing algal biomass. Biohydrogen production was carried out by thermophilic dark fermentation using mixed culture. The culture of *Chlorella sorokiniana* was cultivated in helical airlift photobioreactor at 30 °C under continuous light intensity of 120 μmol m^{-2} s^{-1} provided by white fluorescent lamps. Biomass reached to stationary phase on the ninth day giving maximum dry cell weight of 2.9 kg m^{-3}. Maximum carbohydrate and protein content observed was 145 and 140 g kg^{-1}, respectively. A maximum volumetric productivity of 334 g dm^{-3} d^{-1} was observed. Algal biomass was subjected to various physical and chemical pretreatment processes for the improvement of hydrogen production. It was observed that the pretreatment with 200 dm^3 m^{-3} HCl-heat was most suitable pretreatment method producing cumulative hydrogen of 1.93 m^3 m^{-3} and hydrogen yield of 958 dm^3 kg^{-1} volatile suspended solid or 2.68 mol mol^{-1} of hexose. Growth kinetics parameters such as μ_{max} and K_s were estimated to be 0.44 h^{-1} and 120 g m^{-3}, respectively. The relationship between biomass and hydrogen production was simulated by the Luedeking–Piret model showing that H_2 production is growth associated. The study thus showed the potential of algal biomass as substrate for biological hydrogen production.

04 BY-PRODUCTS RELATED TO FUELS

14/03146 Characteristics of solid by-products from entrained flow gasification of Australian coals

Ilyushechkin, A. Y. *et al. Fuel Processing Technology*, 2014, 118, 98–109.

Coal mineral matter undergoes a series of transformations during entrained flow gasification before exiting the gasifier as liquid slag, fly ash, or fly slag. As a result of these transformations, there is the potential for the composition of the slag and fly ash to differ significantly from that of the mineral matter in the feed coal. This work presents new data from the testing of four Australian coals in a 5 MW_{th} pilot-scale entrained flow gasifier and describes analyses of the morphology, microstructure, and composition of samples of solid by-products obtained from the pilot-scale test program. The results of these analyses indicate some significant differences in composition between the mineral matter of the feed coal and the solid slag and fly ash by-products, which also impacts on the viscosity behaviour of the slags. These differences are primarily attributable to two factors: the partitioning of the mineral matter between fly ash and slag in the gasifier and, in some instances, the interaction of the fresh slag with slag produced from different coals and/or test runs which was already present on the wall of the gasifier.

14/03147 Composition and modes of occurrence of minerals and elements in coal combustion products derived from high-Ge coals

Dai, S. *et al. International Journal of Coal Geology*, 2014, 121, 79–97.

The fly ashes derived from three giant coal-hosted Ge deposits, Lincang (Yunnan, south-western China), Wulantuga (Inner Mongolia, northern China) and Spetzugli (Primorye, Russian Far East), are unique because they are highly enriched in elements, including up to (on an organic-free basis): 4.66% Ge, 2.12% As, 1.56% F, 1.22% Sb, 0.56% W, 0.56% Zn, 0.55% Pb, 0.13% Sn, 0.12% Ga, 0.056% Bi, 0.04% Be, 0.028% Cs, 0.017% Tl and 0.016% Hg. These high element concentrations in the fly ashes are due both to their high levels in the raw coals from which they were derived and their high volatility during the coal combustion process. Rare earth elements and yttrium (REY) were fractionated during coal combustion. They are more enriched in fly ashes than in slag from the respective coals. Maximum REY enrichment may occur either in fine-grained fly ash from baghouse filters or in coarse-grained fly ash from electrostatic precipitators. Cerium and Eu are more enriched in the fly ashes than other REY, and yttrium is relatively depleted in the fly ashes in comparison with the slag. Three types of unburnt carbon can be identified in the fly ashes: (1) carbon with well-preserved initial maceral structures (fusinite and secretinite), (2) isotropic and anisotropic carbon and (3) secondary fine-grained carbon. The last type of unburnt carbon is characterized by embedded fine-grained Ge-bearing and other mineral phases. Ge oxides (e.g. GeO_2) are the major Ge carrier in the fly ashes. Other Ge-bearing mineral phases, however, were also identified, including glass, Ca ferrites, solid solutions of Ge in SiO_2, and probably elemental Ge or Ge (Ge-W) carbide, as well as previously-unknown complex oxides including $(Ge,As)O_x$, $(Ge,As,Sb)O_x$, $(Ge,As,W)O_x$, and $(Ge,W)O_x$. Some portion of the Ge occurs as adsorbed species in different types of unburnt carbon (types 1 and 2) in the ash particles.

14/03148 Conversion and leaching characteristics of biomass ashes during outdoor storage – results of laboratory tests

Supancic, K. *et al. Biomass and Bioenergy*, 2014, 61, 211–226.

Laboratory storage tests were performed with different ash fractions from fixed and fluidized combustion plants utilizing wood chips and bark. There, the ash fractions were stored under varying conditions (dry, wet, open, airtight) over 16 weeks to investigate the changes in physical and chemical properties of the ashes. The results show that the main chemical reactions during storage are the formation of $Ca(OH)_2$ from CaO and H_2O and a water uptake by poorly crystallized or amorphous phases. The ash samples showed only a rather small increase in the TIC mass fraction so the carbonation of $Ca(OH)_2$ with CO_2 to form $CaCO_3$ played only a minor role during the time period investigated. Other reactions like the formation of ettringite or gypsum (due to the small amount of S contained in the ashes investigated) were not observed. Regarding the leaching characteristics, the Ca leaching ratio decreases over time while the K and Na leaching ratios increase. The results regarding the water demand during storage indicate that the mass fraction of Ca in the dry material in the ashes is a suitable parameter to determine the optimum water admixing rate to facilitate aging of the ashes.

14/03149 Dynamic study of methanol adsorption on activated carbon ACM-35.4 for enhancing the specific cooling power of adsorptive chillers

Gordeeva, L. and Aristov, Y. *Applied Energy*, 2014, 117, 127–133.

Lower specific cooling power (SCP) as compared to absorption and compression chillers slows down a broader application of adsorption cooling (AC) technology. In this paper, the authors endeavour to find the factors dominating adsorption/desorption dynamics in adsorptive chillers and to make practical recommendations on optimizing the SCP. The working pair studied is activated carbon ACM-35.4–methanol. This carbon is the modern analogue of a well-known carbon AC-35 that has been widely tested for AC units. The authors have experimentally examined the dynamics under a simple, but realistic configuration of a thin adsorbent bed composed of loose grains located on a flat metal plate. The effects of the adsorbent grain size (0.8–4.0 mm), bed thickness (0.8–5.6 mm), and adsorption/desorption temperatures are explored under conditions of isobaric stages of AC cycle. The adsorption rate appears to be mainly controlled by the heat transfer between the adsorbent bed and the heat transfer fluid. The ratio (S/m_{ad}) of the heat transfer area S to the adsorbent mass m_{ad} can be used to assess the degree of dynamic perfection of real adsorber–heat exchanger units. On the basis of the main findings obtained, the practical recommendations on enhancing the SCP of AC units are made.

14/03150 Fly ash from coal combustion – an environmental source of organic compounds

Ribeiro, J. *et al. Applied Geochemistry*, 2014, 44, 103–110.

The fly ash resulting from coal combustion (anthracite A coal type) for power generation was investigated. The fly ash produced during the coal combustion was emplaced in surface landfills near the thermal power plant facilities. A total of six samples were collected in the fly ash landfills which were therefore analysed for their geochemical characterization. The analysis comprised the determination of total organic carbon and total sulfur, the identification of aliphatic hydrocarbons, and the identification and quantification of the 16 priority polycyclic aromatic hydrocarbons (PAHs). This study provides information about the potential environmental impacts associated with the disposal of fly ash and, in addition, it also provides scientific knowledge about the effects of combustion process in the soluble fraction of coal organic matter and about the behaviour of these compounds during combustion. The results about the aliphatic compounds demonstrated that the long-chain n-alkanes, the pentacyclic terpanes, and the regular steranes (C-27, C-28, C-29) increase in fly ash samples comparatively to coal. The PAHs with two and three aromatic rings (low molecular weight PAHs – LMW PAHs) were not detected in fly ash while fluoranthene (four rings) was detected in all samples, and benzo[*a*]anthracene (four rings), benzo[*b*]fluoranthene (four rings), indeno[*123-cd*]pyrene (five rings), benzo[*ghi*]perylene (five rings) and dibenzo[*ah*]anthracene (six rings) were detected in some of the samples. The absence of LMW PAHs and the presence of some high molecular weight PAHs, with four to six rings, are attributed to the combustion process. The low sum of the priority PAHs in fly ash samples can be related with both, the high rank of the coal burned in the thermal power plant (anthracite A), with the technical combustion conditions and/or leaching process in the fly ash landfills. The organic compounds adsorbed in fly ash particles may be released into the environment and therefore can represent a potential source of contamination of soils and waters and human health problems.

14/03151 Pilot-scale road subbase made with granular material formulated with MSWI bottom ash and stabilized APC fly ash: environmental impact assessment

del Valle-Zermeño, R. *et al. Journal of Hazardous Materials*, 2014, 266, 132–140.

A granular material (GM) to be used as road sub-base was formulated using 80% of weathered bottom ash and 20% of mortar. The mortar was prepared separately and consisted in 50% air pollution control (APC) fly ash and 50% of Portland cement. A pilot-scale study was carried on by constructing three roads in order to environmentally evaluate the performance of GM in a real scenario. By comparing the field results with those of the column experiments, the overestimations observed at laboratory scale can be explained by the potential mechanisms in which water enters into the road body and the pH of the media. An exception was observed in the case of Cu, whose concentration release at the test road was higher. The long-time of exposure at atmospheric conditions might have favoured oxidation of organic matter and therefore the leaching of this element. The results obtained showed that immobilization of all heavy metals and metalloids from APC is achieved by the pozzolanic effect of the cement mortar. This is, to the knowledge of the authors, the only pilot scale study that is considering reutilization of APC as a safe way to disposal.

14/03152 Production and characterization of activated carbon from sour cherry stones by zinc chloride

Angin, D. *Fuel*, 2014, 115, 804–811.

The purpose of this study is to produce the low-cost activated carbon from sour cherry (*Prunus cerasus* L.) stones, known as a waste of fruit juice industry, by chemical activation using zinc chloride. The effects of the activation temperature and the impregnation ratio on the surface and chemical properties of activated carbon were investigated. Also, the mathematical correlation between the activation process variables and outputs such as activated carbon yield and surface area were examined by using the Response surface methodology. The activation temperatures and impregnation ratios were selected at the range of 500–900 °C and 1 : 1–4 : 1, respectively. In the study, it was observed that the optimum conditions for the activated carbon production were activation temperature of 700 °C and impregnation ratio of 3 : 1. The optimum conditions resulted in an activated carbon with a carbon content of 80.78% and a yield of 16.22%, while the Brunauer–Emmett–Teller surface area evaluated using nitrogen adsorption isotherm corresponds to 1704 $m^2 g^{-1}$, with the total pore volume of 1.566 $cm^3 g^{-1}$. The activated carbon was heteroporous with the micropore volume contributing to 62.84%. Also, experimental results showed that the activation temperature and the impregnation ratio have significant effects on the pore structure of the activated carbon and sour cherry stones seemed to be an alternative precursor for the commercial activated carbon productions.

14/03153 The effect of fly ash on the rheological properties of bituminous materials

Sobolev, K. *et al. Fuel*, 2014, 116, 471–477.

Fly ash has been effectively used in concrete; however, there are limited applications in which fly ash has been used in asphalt pavements. The reported research demonstrates that the use of fly ash in bitumen materials is an attractive option because it improves performance and reduces costs and environmental impacts. Microstructural investigation demonstrated that the crack-arresting was induced by the fly ash particles evenly distributed within bitumen matrix. To assess the effect of fly ash on the rheological performance of asphalt cement, a dynamic shear rheometer was used to measure the binder's resistance to shear deformation in the linear viscoelastic region. The rutting factor, $G^*/\sin(\delta)$ and dynamic viscosity, η', were determined for different types of bitumen at different temperatures, with 5%, 15%, 30% and 60% of binder replacement by weight of fly ash classes C and F. The addition of fly ash improved the rutting factor and reached a higher performance grade of the binders. The viscosity for both bitumen types increased at 124 °C degrees, but for the most of the compositions it remained within the range for mixing and placement of asphalt concrete.

14/03154 The effect of process parameters on the carbon dioxide based production of activated carbon from lignite in a rotary reactor

Karaman, I. *et al. Fuel Processing Technology*, 2014, 118, 34–41.

Activated carbons were prepared from raw lignite applying a physical activation method with CO_2 in a rotary tube furnace. The effects of process parameters were determined: temperature, activation time, preoxidation time, CO_2 flow rate, heating rate and rotation rate. In general, micropore-rich activated carbons were produced and the operating parameters had a significant influence on the product. Brunauer–Emmett–Teller (BET) surface areas were found to range from 331.5 to 696.4 m^2/g, the total pore volume from 0.1768 to 0.4446 cm^3/g and yield from 61.06% to 11.06%. Raising CO_2 flow rate significantly increased the BET surface area of the product. The operation mode of the reactor was important. The BET surface area of the sample produced with rotation of the reactor is approximately 16% higher than the sample produced without rotation of the reactor, although it appears insensitive to the absolute speed of rotation. It was concluded that rotation of the reactor is an effective way to enhance the production of activated carbon, in terms of increasing surface area without a significant reduction in yield.

14/03155 The experimental study of fly ash recirculation combustion characteristics on a circulating fluidized bed combustor

Mei, L. *et al. Fuel Processing Technology*, 2014, 118, 192–199.

Fly ash recirculation combustion (FARC) technology is an effective way to improve the combustion performance due to the improvement of carbon burnout as well as the utilization of calcium oxide. In order to study the effect of FARC on operation and emission characteristics of circulating fluidized bed (CFB) boilers, a series of experiments were carried out on a laboratory-scale CFB combustor by using two types of fly ash (desulfurization and non-desulfurization fly ashes). Results show that with FARC, the temperature distribution in the furnace becomes uniform. The difference between the two different types of fly ash is mainly reflected in the emissions of SO_2 and NO_x. Desulfurization fly ash would increase the NO_x emission while decrease the SO_2 emission, and the optimum desulfurization temperature is 880 °C. On the contrary, non-desulfurization fly ash would increase SO_2 emission while decrease NO_x emission. FARC could effectively improve the

combustion performance, as the recirculation rate increases from 0 to 0.3, the combustion efficiency increases by 2% for both two fly ashes and the CO emission decreases, but the particulate matter emission increases. For desulfurization fly ash, Ca/S molar ratio should be appropriately reduced for inhibiting the NO_x emission when limestone was used for *in situ* desulfurization.

05 NUCLEAR FUELS

Scientific, technical

14/03156 A method for on-line reactivity monitoring in nuclear reactors

Dulla, S. *et al. Annals of Nuclear Energy*, 2014, 65, 433–440.

This study considers the problem of the on-line monitoring of the reactivity in a source-free nuclear reactor. The method is based on the classic point kinetic model of reactor physics. A relationship between the instantaneous value of the system stable period and the values of the neutron flux amplitude (or the power), of its derivative and of the integral convolution term determining the instantaneous value of the effective delayed neutron concentration is derived. The reactivity can then be evaluated through the application of the inhour equation, assuming the effective delayed neutron fraction and prompt generation time are known from independent measurements. Since the power-related quantities can be assumed to be experimental observables at each instant, the reactivity can be easily reconstructed. The method is tested at first through the interpretation of power histories simulated by the solution of the point kinetic equations; the effect of the time interval between power detections on the accuracy is studied, proving the excellent performance of the procedure. The work includes also a study on the sensitivity of the reactivity forecast to the uncertainty on the values of the effective delayed neutron fraction and prompt generation time. The spatial effects are investigated by applying the method to the interpretation of flux evolution histories generated by a numerical code solving the space–time-dependent neutron kinetic equations in the diffusion model. Also in this case the method proves to be quite effective in providing good estimates of the system reactivity, except at very short times after the introduction of a perturbation inducing a spatial transient. At last, the effect of the experimental noise is investigated, proving that the consequences in the accuracy of the reactivity prediction can be mitigated by using an adequate differentiation algorithm.

14/03157 Advanced surveillance of resistance temperature detectors in nuclear power plants

Montalvo, C. *et al. Annals of Nuclear Energy*, 2014, 65, 35–40.

The dynamic response of several resistance temperature detectors (RTDs) located at the cold leg of a pressurized water reactor has been studied. A theoretical model for the heat transfer between the RTDs and the surrounding fluid is derived. It proposes a two real poles transfer function. By means of noise analysis techniques in the time domain (autoregressive models) and the dynamic data system methodology, the two time constants of the system can be found. A Monte Carlo simulation is performed in order to choose the proper sampling time to obtain both constants. The two poles are found and they permit an advance *in situ* surveillance of the sensor response time and the sensor dynamics performance. One of the poles is related to the inner dynamics whereas the other one is linked to the process and the inner dynamics. So surveillance on the process and on the inner dynamics can be distinguished.

14/03158 Analysis of magnetic Rayleigh–Taylor instability in a direct energy conversion system which converts inertial fusion plasma kinetic energy into pulsed electrical energy

Sijoy, C. D. and Chaturvedi, S. *Annals of Nuclear Energy*, 2013, 62, 81–85.

A direct energy conversion scheme to convert plasma kinetic energy into pulsed electrical energy, based on magnetic flux compression (MFC) by an inertial fusion plasma sphere, has been examined earlier. The plasma sphere, expanding across a magnetic field, is subject to the magnetic Rayleigh–Taylor (MRT) instability. Therefore, two-dimensional magnetohydrodynamic simulations have been performed to analyse the MRT instability and its implications for the proposed MFC system. The simulation takes into account the effects of MFC and geometric divergence due to spherical plasma expansion. Single-mode sinusoidal perturbation evolution exhibits linear exponential growth followed by a non-linear phase towards stagnation time. The study also notes that near the time of stagnation, the growth in amplitude of the modes, although exponential in nature, is much lower than the growth predicted by linear theory. Furthermore, the instability amplitudes are not large enough for $\alpha_{in} \leq 0.1\lambda_{in}$ to severely disturb the smooth MFC during the first expansion phase. However, the growth of modes with $\alpha_{in} \geq \lambda_{in}$ causes plasma jetting, especially for longer λ modes, and can lead to significant reduction in MFC efficiency.

14/03159 Characterization of Ni–20Cr–5Al model alloy in supercritical water

Huang, X. and Guzonas, D. *Journal of Nuclear Materials*, 2014, 445, (1–3), 298–307.

MCrAlY is a class of coating materials that provide corrosion and oxidation resistance to many Ni and Fe based alloys by forming dense alumina layer on the surface. In order to assess its potential as corrosion resistant coatings on components in supercritical water-cooled nuclear reactors, a Ni–20Cr–5Al model alloy is tested in supercritical water (SCW) (500 °C and 25 MPa) for over 6000 h. The long-term corrosion behaviour of the samples with various surface preparations is evaluated by measuring weight change and examining surface microstructure and oxide formation. The results show that surface preparation alone can lead to changes in weight gain as great as an order of magnitude. Smooth and near stress free surface allows for more oxidation to take place in SCW, hence more weight change. Simple grinding with abrasive paper yields the least and most stable weight change while grit blasting has some effect in reducing weight gain. Comparing to other alloys tested under similar condition, Ni–20Cr–5Al has the lowest weight change. Although not detected, the formation of Al_2O_3 or an Al-modified Cr_2O_3 superficial layer is likely the reason for such low weight change.

14/03160 Comparing neutronics codes performance in analyzing a fresh-fuelled research reactor core

Savva, P. *et al. Annals of Nuclear Energy*, 2014, 63, 731–741.

In this paper, the relative performance of different simulation approaches is examined, focusing on the neutron fluence rate distribution in a nuclear reactor core. The main scope of the work is to benchmark and validate the neutronics code systems utilized in the Greek research reactor (GRR-1) for a high-density low-enriched uranium (LEU) core of compact size. For this purpose the recently converted core of the Portuguese research reactor (RPI), fuelled with fresh, low enrichment in U-235 fuel, was simulated with the stochastic code TRIPOLI and the deterministic code system XSDRN/CITATION. RPI was selected on the basis that it is a similar to GRR-1 pool-type reactor, using same fuel and control rods type, as well as same types of coolant, moderator and reflector. The neutron fluence rate in RPI was computed using each numerical approach with changed approximations. In this frame the stochastic code TRIPOLI was tested using two different nuclear data libraries, i.e. ENDF/B-VI versus JEFF3.1, and two different ways of source definition, i.e. 'point sources', placed in the centre of each fuel cell, versus a 'distributed source', where each fuel volume was considered as a neutron source. The deterministic code system XSDRN/CITATION was tested with respect to the definition of the transverse leakages associated to each one-dimensional, user-defined core zone, as analysed by the XSDRN code in order to provide the zone equivalent cross-sections. Thermal, epithermal and fast neutron fluence rates were computed and local values found in a 15 cm segment immediately below the fuel mid-height were compared to activation foil measurements, as well as to corresponding MCNP results obtained at the RPI. The comparisons were performed in representative core positions, including standard fuel assemblies, dummy (non-fuelled) assemblies, beryllium reflectors and free grid positions close to the core. Application options and future improvements of the tested codes are discussed. Finally it is worth noting that this paper, including measurements and calculations by three different codes and tests of different cross-section libraries for a new commissioned core, can provide useful material for benchmarking neutronics codes that are under development in various reactor laboratories, as well for optimizing codes already in use.

14/03161 Conceptual design study of Hyb-WT as fusion–fission hybrid reactor for waste transmutation

Siddique, M. T. and Kim, M. H. *Annals of Nuclear Energy*, 2014, 65, 299–306.

This study proposes a conceptual design of a hybrid reactor for waste transmutation (Hyb-WT). The design of Hyb-WT is based on a low-power tokamak (<150 MWt) and an annular ring-shaped reactor core with metal fuel (TRU 60 w/o, Zr 40 w/o) and a fission product (FP) zone. The computational code systems MONTEBURNS and MCNPX2.6 are investigated for their suitability in evaluating the performance of Hyb-WT. The overall design performance of the proposed reactor is determined by considering pin-type and tube-in-duct core designs. The objective of such consideration is to explore the possibilities for enhanced transmutation with reduced wall loading from fusion neutrons and reduced transuranic (TRU) inventory. TRU

and FP depletion is analysed by calculating waste transmutation ratio, mass burned per full power year (in units of kg/fpy), and support ratio. The radio toxicity analysis of TRUs and FPs is performed by calculating the percentage of toxicity reduction in TRU and FP over a burn cycle.

14/03162 Coupling between mechanical and transfer properties and expansion due to DEF in a concrete of a nuclear power plant

Al Shamaa, M. *et al. Nuclear Engineering and Design*, 2014, 266, 70–77.
This paper focuses on studying the consequences of expansion due to delayed ettringite formation (DEF) on transfer and mechanical properties of concrete in the case of nuclear structures. It concerns a concrete representative of a containment vessel of a nuclear power plant where temperature variations at early age are very large. An experimental heat treatment, representative of the temperature history in the raft foundation of the containment vessel was reproduced after a modelling of its temperature rise. After this treatment, concrete exhibits swelling due to the development of DEF. The gas permeability is increased significantly after swelling, and the safety requirements expected by these structures are thus affected.

14/03163 Effects of temperature on stress corrosion cracking behavior of stainless steel and outer oxide distribution in cracks due to exposure to high-temperature water containing hydrogen peroxide

Nakano, J. *et al. Journal of Nuclear Materials*, 2014, 444, (1–3), 454–461.
Cracking growth tests were conducted in high-temperature water containing hydrogen peroxide (H_2O_2) at 561–423 K to evaluate the effects of H_2O_2 on stress corrosion cracking (SCC) of stainless steel (SS) at temperature lower than the boiling water reactor (BWR) operating temperature. Small compact tension (CT) specimens were prepared from thermally sensitized type 304 SS. Despite the observation of only a small portion intergranular SCC (IGSCC) near the side groove of the CT specimen at 561 K in high-temperature water containing 100 ppb H_2O_2, the IGSCC area expanded to the central region of the CT specimens at 423 and 453 K. Effects of H_2O_2 on SCC appeared intensely at temperature lower than the BWR operating temperature because of a reduction in the thermal decomposition of H_2O_2. To estimate the environment in the cracks, outer oxide distribution on the fracture surface and the fatigue pre-crack were examined by laser Raman spectroscopy and thermal equilibrium calculation was performed.

14/03164 Estimation of the caesium-137 source term from the Fukushima Daiichi nuclear power plant using a consistent joint assimilation of air concentration and deposition observations

Winiarek, V. *et al. Atmospheric Environment*, 2014, 82, 268–279.
Inverse modelling techniques can be used to estimate the amount of radionuclides and the temporal profile of the source term released in the atmosphere during the accident of the Fukushima Daiichi nuclear power plant in March 2011. In an earlier study, the lower bounds of the caesium-137 and iodine-131 source terms were estimated with such techniques, using activity concentration measurements. The importance of an objective assessment of prior errors (the observation errors and the background errors) was emphasized for a reliable inversion. In such critical context where the meteorological conditions can make the source term partly unobservable and where only a few observations are available, such prior estimation techniques are mandatory, the retrieved source term being very sensitive to this estimation. The authors propose to extend the use of these techniques to the estimation of prior errors when assimilating observations from several data sets. The aim is to compute an estimate of the caesium-137 source term jointly using all available data about this radionuclide, such as activity concentrations in the air, but also daily fallout measurements and total cumulated fallout measurements. It is crucial to properly and simultaneously estimate the background errors and the prior errors relative to each data set. A proper estimation of prior errors is also a necessary condition to reliably estimate the *a posteriori* uncertainty of the estimated source term. Using such techniques, a total released quantity of caesium-137 in the range of 11.6–19.3 PBq was retrieved with an estimated standard deviation range of 15–20% depending on the method and the data sets. The 'blind' time intervals of the source term have also been strongly mitigated compared to the first estimations with only activity concentration data.

14/03165 High stress monitoring of prestressing tendons in nuclear concrete vessels using fibre-optic sensors

Perry, M. *et al. Nuclear Engineering and Design*, 2014, 268, 35–40.
Maintaining the structural health of prestressed concrete nuclear containments is a key element in ensuring nuclear reactors are capable of meeting their safety requirements. This paper discusses the attachment, fabrication and characterization of optical fibre strain sensors suitable for the prestress monitoring of irradiated steel prestressing tendons. The all-metal fabrication and welding process allowed the instrumented strand to simultaneously monitor and apply stresses up to 1300 MPa (80% of steel's ultimate tensile strength). There were no adverse effects to the strand's mechanical properties or integrity. After sensor relaxation through cyclic stress treatment, strain transfer between the optical fibre sensors and the strand remained at 69%. The fibre strain sensors could also withstand the non-axial forces induced as the strand was deflected around a 4.5 m bend radius. Further development of this technology has the potential to augment current prestress monitoring practices, allowing distributed measurements of short- and long-term prestress losses in nuclear prestressed-concrete vessels.

14/03166 Impact of nuclear irradiation on helium bubble nucleation at interfaces in liquid metals coupled to permeation through stainless steels

Fradera, J. and Cuesta-López, S. *Fusion Engineering and Design*, 2014, 89, (1), 16–24.
The impact of nucleating gas bubbles in the form of a dispersed gas phase on hydrogen isotope permeation at interfaces between liquid metals, like LLE, and structural materials, like stainless steel, has been studied. Liquid metal to structural material interfaces involving surfaces, may lower the nucleation barrier promoting bubble nucleation at active sites. Hence, hydrogen isotope absorption into gas bubbles modelling and control at interfaces may have a capital importance regarding design, operation and safety. He bubbles as a permeation barrier principle is analysed showing a significant impact on hydrogen isotope permeation, which may have a significant effect on liquid metal systems, e.g. tritium extraction systems. Liquid metals like LLE under nuclear irradiation in, e.g. breeding blankets of a nuclear fusion reactor would generate tritium which is to be extracted and recirculated as fuel. At the same time that tritium is bred, helium is also generated and may precipitate in the form of nano bubbles. Phenomena modelling is exposed and implemented in openFROM CFD tool for 0D to 3D simulations. Results for a 1D case show the impact of a He dispersed phase of nano bubbles on hydrogen isotopes permeation at an interface. In addition, a simple permeator simulation, consisting in a straight 3D pipe is exposed showing the effect of a He dispersed gas phase on hydrogen isotope permeation through different stainless steels. Results show the permeation reduction as a function of the interface area covered by He bubbles. This work highlights the effect of gas bubble nucleation at interfaces and the importance of controlling these phenomena in nuclear technology applications.

14/03167 Influence of boron carbide on core degradation during severe accidents in LWRs

Steinbrück, M. *Annals of Nuclear Energy*, 2014, 64, 43–49.
Boron carbide (B_4C) is widely used as neutron absorbing control rod material in light water reactors. It was also applied in all units of the Fukushima Dai-ichi nuclear power plant. Although the melting temperature of B_4C is 2450 °C, it initiates local, but significant melt formation in the core at temperatures around 1250 °C due to eutectic interactions with the surrounding steel structures. The B_4C containing melt relocates and hence transports material and energy to lower parts of the fuel bundle. It is chemically aggressive and may attack other structure materials. Furthermore, the absorber melt is oxidized by steam very rapidly and thus contributes to the hydrogen source term in the early phase of a severe accident. After failure of the control rod cladding B_4C reacts with the oxidizing atmosphere. This reaction produces CO, CO_2, boron oxide and boric acids, as well as significant amount of hydrogen. It is strongly exothermic, thus causing considerable release of energy. No or only insignificant formation of methane was observed in all experiments with boron carbide. The paper will summarize the current knowledge on boron carbide behaviour during severe accidents mainly based on experiments performed at the Karlsruhe Institute of Technology in Germany, and will try, also in the light of the Fukushima accidents, to draw some common conclusions on the behaviour of B_4C during severe accidents with the main focus on the consequences for core degradation and hydrogen source term.

14/03168 Modeling of oxygen gas diffusion and consumption during the oxic transient in a disposal cell of radioactive waste

De Windt, L. *et al. Applied Geochemistry*, 2014, 41, 115–127.
The oxic transient in geological radioactive waste disposal is a key issue for the performance of metallic components that may undergo high corrosion rates under such conditions. A previous study carried out *in situ* in the argillite formation of Tournemire in France has suggested that oxic conditions could have lasted several years. In this study, a multiphase reactive transport model is performed with the code HYTEC to analyse the balance between the kinetics of pyrite oxidative dissolution, the kinetics of carbon steel corrosion and oxygen gas diffusion when carbon steel components are emplaced in the geological

medium. Two cases were modelled: first, the observations made *in situ* have been reproduced, and the model established was then applied to a disposal cell for high-level waste in an argillaceous formation, taking into account carbon steel components and excavated damaged zones. In a closed system, modelling leads to a complete and fast consumption of oxygen in both cases. Modelling results are more consistent with the *in situ* test while considering residual voids between materials and/or a water unsaturated state allowing for oxygen gas diffusion (open conditions). Under similar open conditions and considering ventilation of the handling drifts, a redox contrast occurs between reducing conditions at the back of the disposal cell (with anoxic corrosion of steel and H_2 production) and oxidizing conditions at the front of the cell (with oxic corrosion of steel). The extent of the oxidizing/reducing front in the disposal cell is strongly dependent on the gas diffusion coefficient in partially saturated zones.

14/03169 Monitoring radiation embrittlement during life extension periods

Ballesteros, A. *et al. Nuclear Engineering and Design*, 2014, 267, 197–206.

This paper presents guidelines to monitor the radiation embrittlement of reactor pressure vessels (RPV) during life extension periods (to 60 or 80 years) or for the long-term operation of nuclear power plants (NPPs). The guidelines were developed in 2012–2013 by a task group of the international project LONGLIFE. The work performed responds to the need for guidance to treat long-term irradiation effects within the ageing management of NPPs, since the standard RPV surveillance programmes were designed only to cover a time period of 40 years. The guidelines are intended to support specialists in the field and managers in the plant to choose among the most adequate techniques and methods available today to extend the use of their current RPV surveillance programme beyond design life, or implement a new programme when needed. The study performed identifies weaknesses in the ability of the standard surveillance programmes to provide data needed for long term operation, and proposes solutions and tools to solve and/or mitigate the lack or scarcity of surveillance material for their use in life extension. Guidance is also given on methods and strategies to generate reliable surveillance data in the high fluence range.

14/03170 Optimization study for thermal efficiency of supercritical water reactor nuclear power plant

Su, Y. *et al. Annals of Nuclear Energy*, 2014, 63, 541–547.

The thermal efficiency of a supercritical water reactor (SCWR) nuclear power plant is studied here. It is affected by three feedwater regenerative parameters namely enthalpy rise distribution of heaters, corresponding optimum feedwater temperature and number of regenerative stage. These parameters are interlinked. The steam cycle system of SCWR contains two-stage reheating and eight-stage regenerative system. The average distribution method is used to study the relationships between these parameters. Different thermal efficiency parameters of the circulating system in SCWR are calculated and optimized. The results can be a good reference for the design of steam circulation system in SCWR design. The correct temperature of 280 °C will be selected for the core inlet. Based on the investigation of existing supercritical steam turbine technology of the supercritical fossil power plant, some useful suggestions are given for the steam turbine design of SCWRs.

14/03171 Power probability density function control and performance assessment of a nuclear research reactor

Abharian, A. E. and Fadaei, A. H. *Annals of Nuclear Energy*, 2014, 64, 11–20.

One of the main issues in controlling a system is to keep track of the conditions of the system function. The performance condition of the system should be inspected continuously, to keep the system in reliable working condition. In this study, the nuclear reactor is considered as a complicated system and a principle of performance assessment is used for analysing the performance of the power probability density function (PDF) of the nuclear research reactor control. First, the model of the power PDF is set up, then the controller is designed to make the power PDF for tracing the given shape, that make the reactor to be a closed-loop system. The operating data of the closed-loop reactor are used to assess the control performance with the performance assessment criteria. The modelling, controller design and the performance assessment of the power PDF are all applied to the control of Tehran Research Reactor power in a nuclear process. In this paper, the performance assessment of the static PDF control system is discussed, the efficacy and efficiency of the proposed method are investigated, and finally its reliability is proven.

14/03172 Pre-conceptual core design of SCWR with annular fuel rods

Zhao, C. *et al. Nuclear Engineering and Design*, 2014, 267, 23–33.

The new design of supercritical light water reactor (SCWR) was proposed using annular fuel assemblies. Annular fuel consists of several concentric rings. Feed water flows through the centre and outside of the fuel to give both internal and external cooling. Thanks to this feature, the fuel centre temperature and the cladding temperature can be reduced and high power density can be achieved. The water flowing through the centre also provides moderation, so there is no need for extra water rods in the assembly. The power distribution can be easily flattened by use of this design. The geometry of the annular fuel has been optimized to achieve better performance for the SCWR. There are 19 fuel pins in an assembly. Burnable poison is utilized to reduce the initial excess reactivity. The fuel reloading pattern and water flow scheme were optimized to achieve more uniform power distribution and lower cladding temperature. An equilibrium core has been designed and analysed using three dimensional neutronics and thermal-hydraulics coupling calculations. The void reactivity, Doppler coefficient and cold shut down margin were calculated for safety consideration. The present results show that this concept is a promising design for the SCWR.

14/03173 Reactivity of nitrate and organic acids at the concrete–bitumen interface of a nuclear waste repository cell

Bertron, A. *et al. Nuclear Engineering and Design*, 2014, 268, 51–57.

This study investigates the fate of nitrate and organic acids at the bitumen–concrete interface within repository cell for long-lived, intermediate-level, radioactive wastes. The interface was simulated by a multiphase system in which cementitious matrices (CEM V cement paste specimens) were exposed to bitumen model leachates consisting of nitrates and acetic acid with and without oxalic acid, chemical compounds likely to be released by bitumen. Leaching experiments were conducted with daily renewal of the solutions in order to accelerate reactions. The concentrations of anions (acetate, oxalate, nitrate, and nitrite) and cations (calcium, potassium) and the pH were monitored over time. Mineralogical changes of the cementitious matrices were analysed by X-ray diffraction. The results confirmed the stability of nitrates in the abiotic conditions of the experiments. The action of acetic acid on the cementitious matrix was similar to that of ordinary leaching in the absence of organic acids (i.e. carried out with water or strong acids); no specific interaction was detected between acetate and cementitious cations. The reaction of oxalic acid with the cementitious phases led to the precipitation of calcium oxalate salts in the outer layer of the matrix. The concentration of oxalate was reduced by 65% inside the leaching medium.

14/03174 Research on the leak-rate characteristics of leak-before-break (LBB) in pressurized water reactor (PWR)

Wang, M. *et al. Applied Thermal Engineering*, 2014, 62, (1), 133–140.

Leak rate calculation is the foundation of leak-before-break (LBB) technology application in pressurized water reactors (PWRs). In the paper, a leak rate Mathcad calculation code with different critical flow mathematical assumptions was completed. The code calculation results were contrasted from the published experimental data. The compared results show that the code calculation results are coincident with experimental data. However, the theoretical results are greater than experimental data with different crack L/D, stagnation pressures and subcooled temperatures in case of ignoring friction effect. While the crack friction effect is considered, the calculated results are well in accordance with the experimental data. Also, the different pressure drops are obtained and studied with variations of important parameters in detail. It demonstrates that the friction effect is a significant factor and must be considered in the crack leak rate calculation. The Mathcad code can be used to calculate the crack leak rate and provide application foundation of LBB in PWR pipe systems.

14/03175 Self-adaptive global best harmony search algorithm applied to reactor core fuel management optimization

Poursalehi, N. *et al. Annals of Nuclear Energy*, 2013, 62, 86–102.

The aim of this work is to apply the newly developed optimization algorithm, 'self-adaptive global best harmony search' (SGHS), for pressurized water reactors' (PWRs) fuel management optimization. The SGHS algorithm has some modifications in comparison with basic harmony search (HS) and global-best harmony search (GHS) algorithms such as dynamically change of parameters. For the demonstration of SGHS ability to find an optimal configuration of fuel assemblies, basic HS and GHS algorithms also have been developed and investigated. For this purpose, self-adaptive global best harmony search nodal expansion package (SGHSNE) has been developed implementing HS, GHS and SGHS optimization algorithms for the fuel management operation of nuclear reactor cores. This package uses a developed average current nodal expansion code which solves the multi-group diffusion equation by using the first and second orders of the nodal expansion method for two-dimensional, hexagonal and rectangular geometries, respectively, by one node per fuel assembly.

Loading pattern optimization was performed using SGHSNE package for some test cases to present the SGHS algorithm capability in converging to near optimal loading pattern. Results indicate that the convergence rate and reliability of the SGHS method are quite promising and practically, SGHS improves the quality of loading pattern optimization results relative to HS and GHS algorithms. As a result, it has the potential to be used in the other nuclear engineering optimization problems.

14/03176 Sintering and characterization of ZrN and (Dy,Zr)N as surrogate materials for fast reactor nitride fuel

Pukari, M. and Takano, M. *Journal of Nuclear Materials*, 2014, 444, (1–3), 7–13.

Pellets of inert matrix material ZrN, and surrogate nitride fuel material $(Dy_{0.4}Zr_{0.6})N$, are fabricated for the purpose of investigating the origin and the effect of carbon and oxygen impurity concentrations. Oxygen concentrations of up to 1.2 wt% are deliberately introduced into the materials with two separate methods. The achievable pellet densities of these materials, as a function of O content, sintering temperature and dimensional powder properties are determined. O dissolved into (Dy, Zr)N increases the achievable densities to a larger extent than if dissolved into ZrN. The segregation of O-rich phases in ZrN indicates a low O solubility in the material. Oxygen pick-up during the fabrication of the product as well as its exposure to air is demonstrated. The quality of the materials is monitored by the systematic analysis of O, N and C contents throughout the fabrication and sintering processes, supported by X-ray diffraction and scanning electron microscopy analyses.

14/03177 The timing system on the J-TEXT tokamak

Zheng, W. *et al. Fusion Engineering and Design*, 2014, 89, (1), 11–15.

This paper describes the timing system designed to control the operation time-sequence and to generate clocks for various sub-systems on the J-TEXT tokamak. The J-TEXT timing system is organized as a distributed system which is connected by a tree-structured optical fibre network. It can generate delayed triggers and gate signals (0 μs–4000 s), while providing reference clocks for other sub-systems. Besides, it provides event handling and timestamping functions. It is integrated into the J-TEXT control, data access and communication system, and it can be monitored and configured by experimental physics and industrial control system. The configuration of this system including tree-structured network is managed in XML files by dedicated management software. This system has already been deployed on J-TEXT tokamak and it is serving J-TEXT in daily experiments.

14/03178 Thermal stability of nanoscale helium bubbles in a 14YWT nanostructured ferritic alloy

Edmondson, P. D. *et al. Journal of Nuclear Materials*, 2014, 445, (1–3), 84–90.

A 14YWT nanostructured ferritic alloy has been irradiated with 335 keV He^+ to a total fluence of 6.75×10^{20} He m^{-2} at a temperature of 400 °C and subsequently thermally treated at 750 °C for up to 100 h. Transmission electron microscopy has been used to characterize the size and distribution of the resultant helium bubbles. The results indicate that the bubbles generally increase in size and the distribution becomes more inhomogeneous during the thermal treatment. The results are discussed in terms of the helium supply and vacancy supersaturation, Brownian motion and coalescence, and Ostwald ripening mechanisms.

14/03179 Thermo-mechanic behavior simulation for fuel assemblies manufactured in Mexico with FEMAXI-VI code

Hernandez-Lopez, H. *Annals of Nuclear Energy*, 2014, 64, 100–106.

The fuel manufacturing pilot facility from the National Institute for Nuclear Research (ININ), Mexico, provided four GE9B-type fuel assemblies to Laguna Verde Nuclear Power Plant. The fuel irradiation was performed for four operation cycles, highlighting the fact that in the third cycle, the four assemblies, after a certain amount of time, were placed at centre of reactor core. Studies were performed at ININ to evaluate its neutronic performance and to be able to determine the exposure levels of such fuel. Also, the need to perform a thermo-mechanical behaviour study for the fuel rods comprising the assemblies was proposed; this analysis was done with the FEMAXI-VI code.

14/03180 Topographical global optimization applied to nuclear reactor core design: some preliminary results

Sacco, W. F. *et al. Annals of Nuclear Energy*, 2014, 65, 166–173.

The nuclear reactor core design optimization problem consists in adjusting several reactor cell parameters, such as dimensions, enrichment and materials, in order to minimize the average peak-factor in a three-enrichment-zone reactor, considering restrictions on the average thermal flux, criticality and sub-moderation. This problem is highly multimodal, requiring optimization techniques that overcome local optima. In order to do so, a clustering optimization technique was used based on the topographical information on the objective function called topographical global optimization (TGO). This algorithm consists of three steps: a uniform random sampling of solutions in the search space, the construction of the topograph, and the application of a local optimization algorithm using the topograph minima as starting points. In this work, the Sobol quasi-random sequence was used to perform the first step and the Hooke–Jeeves direct search method (HJ), which is one of the less sophisticated algorithms of this type, for the third step. In spite of HJ's simplicity, the results are competitive in terms of fitness function values, being obtained at a computational cost one order of magnitude lower than the efforts required for achieving the best results so far. This fact suggests that better results can be obtained employing more modern and effective direct search methods. Nevertheless, as the problem attacked is quite challenging, the preliminary results show the potential of TGO to be applied to other nuclear science and engineering problems. For the best of the authors' knowledge, this is the first time that TGO is applied to an engineering optimization problem.

14/03181 Towards the thorium fuel cycle with molten salt fast reactors

Heuer, D. *et al. Annals of Nuclear Energy*, 2014, 64, 421–429.

There is currently a renewed interest in molten salt reactors, due to recent conceptual developments on fast neutron spectrum molten salt reactors (MSFRs) using fluoride salts. It has been recognized as a long-term alternative to solid-fuelled fast neutron systems with a unique potential (large negative temperature and void coefficients, lower fissile inventory, no initial criticality reserve, simplified fuel cycle, wastes reduction, etc.) and is thus one of the reference reactors of the generation IV international forum. In the MSFR, the liquid fuel processing is part of the reactor where a small side stream of the molten salt is processed for fission product removal and then returned to the reactor. Because of this characteristic, the MSFR can operate with widely varying fuel compositions, so that the MSFR concept may use as initial fissile load, ^{233}U or enriched uranium or also the transuranic elements currently produced by light water reactors. This paper addresses the characteristics of these different launching modes of the MSFR and the thorium fuel cycle, in terms of safety, proliferation, breeding, and deployment capacities of these reactor configurations. To illustrate the deployment capacities of the MSFR concept, a French nuclear deployment scenario is finally presented, demonstrating that launching the thorium fuel cycle is easily feasible while closing the current fuel cycle and optimizing the long-term waste management via stockpile incineration in molten salt reactors.

14/03182 Viability of the ESS-Bilbao neutron source for irradiation of nuclear fusion materials

Páramo, A. R. *et al. Journal of Nuclear Materials*, 2014, 444, (1–3), 469–474.

The ESS-Bilbao neutron source, currently under construction, is conceived as a multipurpose facility. It will offer a fast neutron beam line for materials irradiation. This paper examines the viability of ESS-Bilbao for experimental studies of fusion materials. Making use of the already designed target station, the authors have calculated the neutron spectrum expected in the fast neutron line. Then, they have studied the neutron irradiation effects in two model materials: iron and silica. They have calculated the expected primary knock-on atom (PKA) spectra and light species production as well as the damage production in these materials. Regarding structural materials, it was concluded that the ESS-Bilbao neutron irradiation facility will play a minor role due to the resulting low neutron fluxes (about two orders of magnitude lower than in fusion reactors). On the other hand, ESS-Bilbao turns out to be relevant for studies of final lenses in laser fusion power plants. A comparison with the conditions expected for HiPER final lenses shows that the fluxes will be only be a factor 5 smaller in ESS-Bilbao and the PKA spectra will be very similar. Taking into account, in addition, that relevant effects on lenses occur from the onset of irradiation, it was concluded that an appropriate irradiation cell with *in situ* characterization techniques will make ESS-Bilbao very attractive for applied neutron damage studies of laser fusion final lenses. Finally, the authors compared ESS-Bilbao with other facilities.

Economics, policy, supplies, forecasts

14/03183 A direct methodology to establish design requirements for human–system interface (HSI) of automatic systems in nuclear power plants

Anuar, N. and Kim, J. *Annals of Nuclear Energy*, 2014, 63, 326–338.

This paper suggests a systematic approach to establishing design requirements for the human–system interface (HSI) between operators and automatic systems. The role of automation in the control of a nuclear power plant (NPP) operation is to support the human operator

and act as an efficient team player to help reduce the human operator's workload. Some of the problems related to the interaction between the human operator and automation are out-of-the-loop performance, mode errors, role change to supervisory role and final authority issues. Therefore, the design of HSI is critical to avoiding breakdowns in communication between the human operator and the system. In this paper, the design requirements for human–system interface of automatic systems are constructed with the help of a tool called the itemized sequence diagram (ISD). Eight levels of automation (LOA) are initially defined in the function allocation and an ISD is drawn for each of the LOA for task allocation. The ISD is a modified version of sequence diagram, which is widely used in systems engineering as well as software engineering. The ISD elements of arrows, messages, actors and alternative boxes collectively show the interactions between the control agents, which are decomposed into four different roles: information acquiring, plant diagnosing, response selecting and response implementing. Eleven design requirements to optimize the human–automation interaction are suggested by using this method. The design requirements produced from the identified interaction points in the ISD are rationalized and how each requirement addresses the issues related to automation is discussed. The study also identifies which requirements address which of the stated automation issues and at which operational process stage each requirement applies to. Finally, the strengths of the proposed methodology and its implication on the HSI design are discussed in comparison with the methodology used to produce the existing guidelines or guidance.

14/03184 A methodology for a risk-based approach to complex scenarios in a long-term safety assessment of a radioactive waste repository

Kim, J.-W. *et al. Nuclear Engineering and Design*, 2014, 268, 58–63.

A methodology for a risk-based approach to complex scenarios in a long-term safety assessment of a radioactive waste repository was developed using a Monte Carlo sampling method. The methodology consists of event characterization, influence evaluation, scenario combination, scenario assessment, and a convergence check. The methodology was applied to a hypothetical repository system considering earthquake events for illustration. Since two independent impacts by earthquakes were considered in the illustration, the complex scenarios could be categorized into five types including the simultaneous occurrence of impacts. From the assessment results, the total risk computed by the new methodology involved the occurrence probabilities of the complex scenarios, and these probabilities were reasonably converging to pseudo-theoretical probabilities. For further study, the characterizations of events and their impacts on a repository system must be preliminarily determined for a successful assessment.

14/03185 A remote handling rate-position controller for telemanipulating in a large workspace

Barrio, J. *et al. Fusion Engineering and Design*, 2014, 89, (1), 25–28.

This paper presents a new haptic rate-position controller, which allows manipulating a slave robot in a large workspace using a small haptic device. This control algorithm is very effective when the master device is much smaller than the slave device. Haptic information is displayed to the user so as to be informed when a change in the operation mode occurs. This controller allows performing tasks in a large remote workspace by using a haptic device with a reduced workspace such as Phantom. Experimental results have been carried out using a slave robot from Kraft Telerobotics and a commercial haptic interface as a master device. A curvature path following task has been simulated using the proposed controller which was compared with the force-position control algorithm. Results obtained show that higher accuracy is obtained when the proposed method is used, spending a similar amount of time to perform the task.

14/03186 Assessment of passive safety system performance under main steam line break accident

Lim, J. *et al. Annals of Nuclear Energy*, 2014, 64, 287–294.

A generation III + boiling water reactor (BWR), which relies on natural circulation, has evolved from earlier BWR designs by incorporating passive safety features which require no emergency injection pump and no operator action or alternating current (AC) power supply. The generation III + BWR's passive safety systems include the automatic depressurization system (ADS), the suppression pool (SP), the standby liquid control system (SLCS), the gravity-driven cooling system (GDCS), the isolation condenser system (ICS), and the passive containment cooling system (PCCS). The ADS is actuated to rapidly depressurize the reactor leading to the GDCS injection. The large amount of water in the SP condenses steam from the reactor. The SLCS provides makeup water to the reactor. The GDCS injects water into the reactor by gravity head and provides cooling to the core. The ICS and the PCCS are used to remove the decay heat from the reactor. The objective of this paper is to analyse the response of passive safety systems under the loss-of-coolant accident. A main steam line break (MSLB) test has been conducted in the Purdue University multi-dimensional integral test assembly (PUMA) which is scaled to represent the generation III + BWR. The main results of PUMA MSLB test were that the reactor coolant level was well above the top of active fuel (TAF) and the reactor containment pressure has remained below the design pressure. In particular, the minimum water level (1.706 m) was 5% higher than the TAF (1.623 m) and the containment maximum pressure (271 kPa) was 35% lower than the safety limit (414 kPa), respectively.

14/03187 Can corrosion and CRUD actually improve safety margins in LWRs?

Buongiorno, J. *Annals of Nuclear Energy*, 2014, 63, 9–21.

It is well known that boiling and quenching heat transfer depends strongly on the morphology and composition of the solid surface through which the heat transfer occurs. The relevant surface features are roughness, wettability (hydrophilicity), porosity, presence of cavities, size and shape of cavities, and thermophysical properties of the surface material. Recent work at the Massachusetts Institute of Technology (MIT) in the USA has explored the separate effects of surface roughness, wettability and porosity on both critical heat flux (CHF) and quenching heat transfer (Leidenfrost point temperature). Briefly, interconnected porosity within a hydrophilic matrix greatly enhances the CHF (by as much as ~60%) and the Leidenfrost temperature (by as much as ~150 °C). Surprisingly, surface roughness has a comparably minor effect on both CHF and quenching. There are opportunities to exploit in light water reactor (LWR) nuclear plants, where CHF and quenching determine the thermal margins in during loss-of-flow and loss-of-coolant accidents, respectively, and the surface of the fuel naturally develops porous hydrophilic layers because of CRUD deposition and corrosion. This paper reviews the MIT experimental database generated using engineered surfaces with carefully-controlled characteristics, and discuss its applications to LWR safety, both design-basis and beyond-design-basis accidents.

14/03188 Cyber security issues imposed on nuclear power plants

Kim, D.-Y. *Annals of Nuclear Energy*, 2014, 65, 141–143.

With the introduction of new technology based on the increasing digitalization of control systems, the potential of cyber attacks has escalated into a serious threat for nuclear facilities, resulting in the advent of the Stuxnet. In this regard, the nuclear industry needs to consider several cyber security issues imposed on nuclear power plants, including regulatory guidelines and standards for cyber security, the possibility of Stuxnet-inherited malware attacks in the future, and countermeasures for protecting nuclear power plants against possible cyber attacks. New cyber attacks will invariably be smarter, stronger, stealthier and more resilient. Consequently, the safety of nuclear power plants may be compromised by cyber attacks, resulting in reactor shutdowns or disastrous accidents. Regulations and guidelines for cyber security of nuclear facilities provide a regulatory position that promotes a defensive strategy consisting of a defensive architecture and a set of security controls, including technical, operational and management controls. Implementing such security controls, including the deployment of the host intrusion detection system and the employment of the intrusion detection/prevention system with automated tools to support near-real-time analyses, may be another effective countermeasures against cyber attacks.

14/03189 Decision-support tool for assessing future nuclear reactor generation portfolios

Jain, S. *et al. Energy Economics*, 2014, 44, 99–112.

Capital costs, fuel, operation and maintenance (O&M) costs, and electricity prices play a key role in the economics of nuclear power plants. Often standardized reactor designs are required to be locally adapted, which often impacts the project plans and the supply chain. It then becomes difficult to ascertain how these changes will eventually reflect in costs, which makes the capital costs component of nuclear power plants uncertain. Different nuclear reactor types compete economically by having either lower and less uncertain construction costs, increased efficiencies, lower and less uncertain fuel cycles and O&M costs, etc. The decision-making process related to nuclear power plants requires a holistic approach that takes into account the key economic factors and their uncertainties. This study presents a decision-support tool that satisfactorily takes into account the major uncertainties in the cost elements of a nuclear power plant, to provide an optimal portfolio of nuclear reactors. The portfolio so obtained, under the model assumptions and the constraints considered, maximizes the combined returns for a given level of risk or uncertainty. These decisions are made using a combination of real option theory and mean–variance portfolio optimization.

14/03190 Dismantling design for a reference research reactor of the WWR type

Lobach, Y. N. and Cross, M. T. *Nuclear Engineering and Design*, 2014, 266, 155–165.

A decommissioning study has been carried out for a reference research reactor of the water–water reactor (WWR) type. Many such reactors were constructed more than 50 years ago and most of them are still in operation. Decommissioning has now become an important consideration. This paper summarizes the main decommissioning steps and, on the basis of the reactor design features, technical aspects of the dismantling and removal of the contaminated/activated components have been analysed. The advisability of the removal of large components, such as the reactor vessel and the heat exchangers, as one piece items has also been demonstrated. Additionally, a work schedule and an estimation of the collective dose for the preparation and implementation of dismantling have been established. The applicability of existing proven dismantling technologies has been identified together with some additional features for the dismantling.

14/03191 Finite element analysis of stresses and deformations occurring in the spent nuclear fuel (SNF) disposal canister deposited in a deep geological repository

Wang, B. *et al. Nuclear Engineering and Design*, 2014, 266, 166–179.

Numerical computer experimental methodologies are investigated for the weight reduction of a spent nuclear fuel (SNF) disposal canister designed to be deposited in a Korean deep geological repository from a pressurized water reactor (PWR). Finite element analyses of stresses and deformations occurring inside the cylindrical canister under the deposited conditions are performed to assess its structural strength at various rotation angles (φ) of the SNF basket. Specifically, the cross-sections of four square tube shaped SNF baskets (assemblies) contained in the canister are rotated. Using a conventional structural analysis and a Kriging method, an optimal rotation angle is determined in relation to canister diameter and weight. Both sets of results are in agreement. It was also determined that the computed deformation changes slightly in relation to variances in rotation angle, while the stress incurred inside the cast iron insert of the canister noticeably changes reaching its highest value at $\varphi = 45^\circ$ while still maintaining safe structural integrity. It is concluded that the diameter of the canister can be reduced from its original design value (102 cm) to 95.8463 cm resulting in a $\sim$16.0% reduction in canister weight for an optimal rotation angle of 45°.

14/03192 Fuzzy MCDM framework for locating a nuclear power plant in Turkey

Erol, I. *et al. Energy Policy*, 2014, 67, 186–197.

Turkey has recently initiated a project to revise its nuclear policy. The revised nuclear energy policy considers searching for possible alternative locations for future nuclear power plants in Turkey. At the most basic level, the public cannot accurately evaluate whether it is willing to support nuclear energy unless it has an idea about where the power plants are likely to be located. It is argued that the selection of a facility location is a multi-criteria decision-making (MCDM) problem including both quantitative and qualitative criteria. In this research, given the multi-criteria nature of the nuclear facility location selection problem, a new decision tool is proposed to rank the alternative nuclear power plant sites in Turkey. The proposed tool is based on fuzzy entropy and *t*-norm-based fuzzy compromise programming to deal with the vagueness of human judgements. Finally, a discussion and some concluding remarks are provided.

14/03193 Hydrogeochemical characterisation and modelling of groundwaters in a potential geological repository for spent nuclear fuel in crystalline rocks (Laxemar, Sweden)

Gimeno, M. J. *et al. Applied Geochemistry*, 2014, 45, 50–71.

Two sites in the eastern coast of Sweden have been investigated by the Swedish Nuclear Fuel and Waste Management Company, within the framework of the site characterization programme, as possible candidates for hosting the proposed repository for the long-term storage of spent nuclear fuel: Forsmark and Laxemar. This study presents the main results concerning the hydrogeochemical characterization of the groundwaters in the second site, Laxemar. The distribution of the main chemical variables in groundwaters are shown and interpreted in combination with the results from speciation–solubility and reaction-path simulations, together with the available mineralogical information. The results indicate that the main processes determining the overall geochemical evolution of the Laxemar groundwaters are advective/diffusive mixing and water–rock interactions driven by past and present climatic changes inducing the input of different recharge waters over time (glacial meltwater, old marine water and modern meteoric water) and affecting the pre-existing very old saline groundwaters in the bedrock. The superimposed effects of these mixing events, deduced from the behaviour of the conservative elements (Cl and $\delta^{18}O$), have generated a rather steep salinity gradient in the groundwater system, with diluted waters in the upper part, brackish waters in the middle, and saline waters in the lower part of the bedrock. The resultant successive disequilibrium states imposed by mixing have conditioned the water–rock interaction processes that have affected the non-conservative elements to different degrees. The main chemical reactions found to be important in controlling some of the variability of these elements and some important parameters like pH and alkalinity, are: aluminosilicate and carbonate dissolution/precipitation, quartz and fluorite equilibrium, cation exchange, and gypsum dissolution. These reactions and their importance in the system are presented in this paper. Once the main hydrogeochemical features of the Laxemar groundwaters and the potentially controlling water–rock interactions in the system have been identified and justified with the help of thermodynamic simulations, a general geochemical conceptual model has been proposed. This model will be used as the basis for predicting the future evolution of the groundwater chemistry as an essential part of the safety assessment of the future repository.

14/03194 Japan's energy conundrum: post-Fukushima scenarios from a life cycle perspective

Pereira, J. P. *et al. Energy Policy*, 2014, 67, 104–115.

This study aimed at evaluating the co-benefit implications of alternative electricity generation scenarios in Japan, in a post-Fukushima context. Four scenarios were designed assuming different shares of energy sources in a 2030 timeframe. Applying a life cycle assessment methodology, scenarios were assessed in terms of cumulative non-renewable energy (NRE) consumption, global warming potential, terrestrial acidification potential (TAP) and particulate matter formation (PMF). Additionally, electricity generation costs were evaluated. Results demonstrate that the current dependence on fossil fuel is unfeasible in the long run, as it results in 14% higher NRE consumption, an increase of 32% on greenhouse gas (GHG) emissions, 29% on TAP and 34% on PMF and 9% higher cost than the baseline scenario under pre-Fukushima conditions. On the other hand, a share of up to 27% of renewable energies is technically possible and would result in a 34% reduction of NRE consumption, 29% decrease of GHG emissions, and contribute to the mitigation of 24% of TAP and PMF impacts, at minor increase of levelized costs. Increasing the share of renewables and phasing-out thermal power would therefore increase the resilience of the Japanese economy toward external oil markets, cope with environmental protection priorities, while promoting economic development.

14/03195 Model for the conversion of nuclear waste melter feed to glass

Pokorny, R. and Hrma, P. *Journal of Nuclear Materials*, 2014, 445, (1–3), 190–199.

The rate of batch-to-glass conversion is a primary concern for the vitrification of nuclear waste, as it directly influences the life cycle of the clean-up process. This study describes the development of an advanced model of the cold cap, which augments the previous model by further developments on the structure and the dynamics of the foam layer. The foam layer on the bottom of the cold cap consists of the primary foam, cavities, and the secondary foam, and forms an interface through which the heat is transferred to the cold cap. Other model enhancements include the behaviour of intermediate crystalline phases and the dissolution of quartz particles. The model relates the melting rate to feed properties and melter conditions, such as the molten glass temperature, foaminess of the melt, or the heat fraction supplied to the cold cap from the plenum space. The model correctly predicts a 25% increase in melting rate when changing the alumina source in the melter feed from $Al(OH)_3$ to AlO(OH). It is expected that this model will be incorporated in the full glass melter model as its integral component.

14/03196 Modeling and system analysis of fuel cycles for nuclear power sustainability (I): uranium consumption and waste generation

Gao, F. and Ko, W. I. *Annals of Nuclear Energy*, 2014, 65, 10–23.

A complete and well-organized nuclear fuel cycle system is the basis for power generation, and therefore a general study on different nuclear fuel cycle options has been performed to explore strategies for the sustainability of nuclear power. Material flows of 13 fuel cycle options covering the open fuel cycle option, and semi-closed and closed options, have been analysed to derive a comprehensive comparison using an equilibrium model, and are mainly focused on the consumption of uranium resources and waste generation. Setting once-through cycling as the basis, spent fuel after interim storage directly sent to geological disposal without further reprocessing, several key data were derived quantitatively, e.g. spent fuel inventory, waste generation [i.e. low- and intermediate-level radioactive waste with short life (LILW-SL), low- and intermediate-level radioactive waste with long life (LILW-LL), high level waste (HLW)], Pu inventory, and the excavation volume of an underground repository. This investigation covers from the front-end of the fuel cycles to the final disposal, which indicates that sodium-cooled fast reactor (SFR)-involved options show clear advantages in controlling HLW generation with regard to waste amount, decay heat, and activity. Moreover, an option that employs a sodium fast reactor to burn the transuranic waste recovered from the

spent fuel of a pressurized water reactor through pyroprocessing shows predominant advantages over other alternatives due to a reduction in the uranium resource consumption, a smaller proliferation-sensitive material inventory, and the least amount of waste generation. The impacts of the conversion ratios on SFR-involved fuel cycles have also been evaluated.

14/03197 Monitoring the oxidation of nuclear fuel cladding using Raman spectroscopy

Mi, H. *et al. Journal of Nuclear Materials*, 2014, 445, (1–3), 7–11.

In order to observe Zircaloy-4 (Zr-4) cladding oxidation within a spent fuel canister, cladding oxidized in air at 500 °C was investigated by micro-Raman spectroscopy to measure the oxide layer thickness. Systematic Raman scans were performed to study the relationship between typical Raman spectra and various oxide layer thicknesses. The thicknesses of the oxide layers developed for various exposure times were measured by cross-sectional scanning electron microscopy. The results of this work reveal that each oxide layer thickness has a corresponding typical Raman spectrum. Detailed analysis suggests that the Raman scattering peaks around wave numbers of $180\,cm^{-1}$ and $630\,cm^{-1}$ are the best choices for accurately determining the oxide layer thickness. After Gaussian–Lorentzian deconvolution, these two peaks can be quantitatively represented by four peaks. The intensities of the deconvoluted peaks increase consistently as the oxide layer becomes thicker and sufficiently strong signals are produced, allowing one to distinguish the bare and oxidized cladding samples, as well as samples with different oxide layer thicknesses. Hence, a process that converts sample oxide layer thickness to optical signals can be achieved.

14/03198 Nuclear data for radioactive waste management

Sartori, E. *Annals of Nuclear Energy*, 2013, 62, 579–589.

Good quality nuclear data are essential to be able to characterize the different radioactive waste forms, and to provide quality prediction of the source term for waste management. Of major importance are data for the build-up of several radionuclides such as actinides and fission products; also decay-heat issues are important. These data are required to study the different scenarios for power production and waste minimization; efforts are devoted to improving the quality of the data through validation against experiments, re-evaluation, adding covariance data for uncertainty quantification. A wealth of validated data is available from several nuclear data centres.

14/03199 Nuclear energy policy in Belgium after Fukushima

Kunsch, P. L. and Friesewinkel, J. *Energy Policy*, 2014, 66, 462–474.

The Belgian nuclear phase-out law imposes closing down in the 2015–2025 period seven nuclear power plants (NPPs) producing more than 50% of the domestic electricity. This creates an urgent problem in the country because of the absence of well-defined capacity-replacement plans. Though a safety-of-supply provision in the law allows for a delayed phase-out, hopes for a technically acceptable schedule have reduced after the Fukushima nuclear disaster in March 2011. In this paper, policy investigations are made with system dynamics. A significant finding from such modelling is that, in contrast to common expectations, a too early nuclear phase-out will not serve the deployment of renewable energy sources and rational use of energy. It is indeed found to primarily benefit to fossil fuel, creating unwanted drawbacks regarding safety of supply, dependency on foreign suppliers, price volatility and increased use of non-renewable and CO_2-emitting fossil fuels.

14/03200 'Nuclear energy sounded wonderful 40 years ago': UK citizen views on CCS

Lock, S. J. *et al. Energy Policy*, 2014, 66, 428–435.

Around the world there is increasing interest from government and industry in the potential for carbon dioxide capture and storage (CCS) technologies to play a part in decarbonization. This paper examines how people with little previous exposure to CCS technology, frame and discuss it, and how in the absence of information, ideas, notions, values and experiences shape opinion. The authors present data from a series of focus groups held with environmental activists, planning councillors, and adult and youth community group members in London in 2012. It was found that views on CCS are shaped strongly by wider factors, particularly trade-offs between different energy futures. Lay-critiques were similar to those put forward by environmental groups and were strongly framed by conceptions of nuclear power. The authors argue that although there is little public disquiet concerning this technology in private opinions were generally negative. This, and the use of nuclear power as a framing device, may present a challenge to policy-makers and industry committed to implementing CCS while promoting education as the main mechanism for public acceptance.

14/03201 Partisan amplification of risk: American perceptions of nuclear energy risk in the wake of the Fukushima Daiichi disaster

Yeo, S. K. *et al. Energy Policy*, 2014, 67, 727–736.

This study examines risk perceptions toward nuclear power before and after the Fukushima Daiichi disaster in Japan using nationally representative survey samples of American adults. On 11 March 2011, a magnitude 8.4 earthquake, the largest in the nation's history, occurred off the coast of Japan. The earthquake produced a devastating tsunami that flooded areas of the Fukushima Daiichi nuclear plant and resulted in a loss of power to the plant's cooling system. In the weeks that followed, the world watched as Japanese and international nuclear power safety experts scrambled to contain the damage and prevent a full meltdown. Although the Fukushima Daiichi disaster was heavily covered in the news media, there is little empirical research on how this coverage impacted audience risk perceptions. This analysis goes beyond examining aggregate risk perceptions, instead focusing on how specific sub-populations responded to the disaster. It was found that ideological groups responded differently to the events in Japan. In particular, risk perceptions among conservatives decreased following the incident. Moreover, it was found that media use exacerbated these effects. Possible explanations for these findings are also explored in this study.

14/03202 Phytoremediation options for radioactively contaminated sites evaluated

Vandenhove, H. *Annals of Nuclear Energy*, 2013, 62, 596–606.

The application of nuclear energy and the use of radionuclides for industrial, medical and research purposes have caused significant contamination of certain sites and their environment which could result in health problems for several centuries if nothing is undertaken to remedy these situations. Dispersed low-level contamination poses a particular challenge to those charged with its remediation. Different phytomanagement options may be applied for the remediation of radioactive contaminated sites. For vast contaminated surfaces, alternative land-use options seem the more feasible options and this management system requires a holistic approach. Plant systems are extensively studied for their effectiveness to sequester radionuclides from soil and water systems. The potential effectiveness of soil phytoextraction is to be carefully evaluated. Active aqueous plant systems are used to study and realize the sequestration of radionuclides from surface waters, including mine drainage and drainage from waste disposal facilities. Some systems were found to be highly effective. Side-effects (costs, treatment of contaminated biomass, potential for ground water contamination, etc.) should be evaluated in depth.

14/03203 Possible pathways for dealing with Japan's post-Fukushima challenge and achieving CO_2 emission reduction targets in 2030

Su, X. *et al. Energy*, 2014, 66, 90–97.

Considering the unclear nuclear future of Japan after the 2011 Fukushima Dai-ichi nuclear power plant accident, this study assesses a series of energy consumption scenarios including the reference scenario, nuclear limited scenarios and current nuclear use level scenario for Japan in 2030 by the Glocal Century Energy Environment Planning model. The simulation result for each scenario is firstly presented in terms of primary energy consumption, electricity generation, CO_2 emission, marginal abatement cost and gross domestic product (GDP) loss. According to the results, energy saving contributes the biggest share in total CO_2 emission reduction, regardless of different nuclear use levels and different CO_2 emission reduction levels. A certain amount of coal generation can be retained in the nuclear limited scenarios due to the applying of carbon capture and storage (CCS). The discussion indicates that Japan needs to improve energy use efficiency, increase renewable energy and introduce CCS in order to reduce the dependence on nuclear power and to achieve CO_2 emission reduction target in 2030. In addition, it is ambitious for Japan to achieve the zero nuclear scenario with 30% CO_2 emission reduction which will cause a marginal abatement cost of 383 US$/tC and up to −2.54% GDP loss from the reference scenario. Dealing with the nuclear power issue, Japan is faced with a challenge as well as an opportunity.

14/03204 Practical application of the MARSSIM process to the site release of a uranium conversion plant following decommissioning

Hong, S. B. *et al. Annals of Nuclear Energy*, 2014, 65, 241–246.

The final stage in the decommissioning process consists of releasing a site and a building from regulatory control. This study describes the practical application of MARSSIM process in performing a site remediation and conducting a final status survey and discuss the lessons learned. The release criterion for the site and the building were set up using site-specific parameters that were calculated using RESRAD and RESRAD-Build codes. The planning stage of the final status survey consisted of classifying the site, identifying the survey units and selecting the background reference area using the data quality objectives process. The planning, implementation and assessment of the final status survey for the site and the building of the uranium conversion plant were carried out to demonstrate that residual

radioactivity levels meet the release criterion. The null hypothesis must reject in order to demonstrate the objective, null hypothesis is that residual radioactivity in the survey unit exceed the release criterion. The survey results containing the hot spots in the building, a non-parametric statistical test (Wilcoxon rank sum) was chosen for assessment due to the presence of the uranium contamination in background soil. The final status survey results showed that the release criteria were satisfied.

14/03205 Radiological assessment for decommissioning of major component in nuclear power plants

Jeong, K.-S. *et al. Annals of Nuclear Energy*, 2014, 63, 571–574.
To establish the decommissioning plan of reactor pressure vessel (RPV) in nuclear power plants, its radiological characteristics was analysed and evaluated. The dose rates of RPV surface and concrete shield were analysed and evaluated. This paper will be expected to be used for decommissioning plan of RPV and reduction plan of dose rate exposure.

14/03206 Risk reduction approach to decommissioning hazards of nuclear facilities

Jeong, K.-S. *et al. Annals of Nuclear Energy*, 2014, 63, 382–386.
Decommissioning activities include both radiological and non-radiological hazards. Radiological hazards are mainly due to radiation exposure whereas non-radiological hazards are mainly due to industrial hazards such as fire, explosions, toxic materials, and electrical and physical hazards. Based on characteristics of decommissioning activities, risk calculation method of decommissioning hazards and countermeasures of radiological hazards and non-radiological hazards were suggested.

14/03207 Safety analysis of a Super LWR with double tube water rods

Tamiya, N. *et al. Nuclear Engineering and Design*, 2014, 266, 129–136.
A supercritical-pressure light water cooled-moderated reactor (Super LWR) with double tube water rods core was designed for simplifying the upper core structure. Coolant flows upward in the fuel channels. Water inventory in the upper dome of the reactor pressure vessel was available for core cooling for the previous two-path core design, but not for the present one. Safety analysis was conducted to evaluate the safety performance of the present core design. Events of abnormal transients, accidents and anticipated transient without scram were included in the analysis. It is clarified that the water inventory in the double tube water rods can work as the coolant source in the event of total loss of feed water flow. The results of safety analysis show that the safety criteria are satisfied for all selected events.

14/03208 Severe accident research at the Transuranium Institute Karlsruhe: a review of past experience and its application to future challenges

Bottomley, P. D. W. *et al. Annals of Nuclear Energy*, 2014, 65, 345–356.
The current situation in Japan is an appropriate time to examine previous research into severe accidents and the current state of European severe accident research to assess what are the priorities for research for existing and future nuclear reactors. The European Commission's SARNET 2 (Severe Accident NETwork of Excellence) programme and its SARP (Severe Accident Research Priorities) assessments have been made and have outlined the future needs as seen from the European Union point of view. There is already considerable research that will be very valuable in analysing and guiding the investigation and remediation activities at Fukushima Daiichi. This includes investigations into previous major accidents and international severe fuel damage projects. Facilities using analogue materials are able to analyse large-scale behaviour of materials, while smaller-scale testing of irradiated fuel for detailed property measurements are important for mechanistic studies. The final (and very important) aspect is application of this information to formulate codes to model the identified mechanisms and also to have their predictions validated by the data. This paper will take examples from the Transuranium Institute's (ITU Karlsruhe's) contribution to projects such as the TMI-2 accident investigation and the Phébus PF bundle and fission product deposit investigations as well as some of the smaller scale testing and modelling support that ITU has performed over the last 20 years. This will show what has been learnt about fuel and structural material degradation and formation of molten materials, fission product release, and subsequent behaviour. Finally some severe accident research perspectives following Fukushima are proposed.

14/03209 Simulation and dose analysis of a hypothetical accident in Sanmen nuclear power plant

Zhu, Y. *et al. Annals of Nuclear Energy*, 2014, 65, 207–213.
In November 2013, an AP1000 nuclear power plant (NPP) will be put into commercial operation. An atmospheric dispersion of radionuclides during a severe hypothetical accident in Sanmen NPP, Zhejiang province, China, is simulated with a Lagrangian particle dispersion model FLEXPART. The accident assumes that a station blackout (SBO) accident occurred on 25 August 2011, 55% core was damaged and 49 radionuclides were released into the atmosphere. This simulation indicates that, during this dispersion, the radioactive plume will cover the mainland China, Taiwan, Japan, North Korea, South Korea and Russia. The radiation dose levels in Japan, North Korea and Russia are the lightest, usually less than 1 mSv. The influenced areas in these countries are 9901, 31,736 and 2,97,524 km^2, respectively; dose levels in Taiwan and South Korea are moderate, no more than 20 mSv. Information about reducing dose should be given to the public. Total influenced areas in these two countries are 3621 and 42,370 km^2, which take up 100% of the land in Taiwan and 35% of the land in South Korea; the worst situation happens in mainland China. The total influenced area is 3×10^6 km^2 and 140,000 km^2 in this area has a dose level higher than 20 mSv. Measurement must be taken to reduce the dose. More than 284,000 residents will face the risk of developing cancer. Furthermore, 96% of this population is mainly concentrated in Zhejiang province, where Sanmen NPP is located.

14/03210 The cost of nuclear electricity: France after Fukushima

Boccard, N. *Energy Policy*, 2014, 66, 450–461.
The Fukushima disaster in Japan has lead the French government to release novel cost information relative to its nuclear electricity programme allowing for the computation of a levelized cost. This study identifies a modest escalation of capital cost and a larger than expected operational cost. Under the best scenario, the cost of French nuclear power over the past four decades is €59/MWh (at 2010 prices) while in the worst case it is €83/MWh. On the basis of these findings, the future cost of nuclear power in France was estimated to be at least €76/MWh and possibly €117/MWh. A comparison with the USA confirms that French nuclear electricity nevertheless remains cheaper. Comparisons with coal, natural gas and wind power are carried out to find the advantage of these.

14/03211 The interactions of strontium and technetium with Fe(II) bearing biominerals: implications for bioremediation of radioactively contaminated land

Thorpe, C. L. *et al. Applied Geochemistry*, 2014, 40, 135–143.
At nuclear-contaminated sites, microbially mediated Fe(III) reduction under alkaline conditions opens up the potential for co-treatment of the groundwater contaminants ^{99}Tc, though reduction to less mobile Tc(IV) phases, and ^{90}Sr, through increased sorption and/or precipitation promoted at higher pH. In the experiments described here, microbial enrichment cultures derived from representative Sellafield sediments were used to probe the effect of microbially mediated Fe(III) reduction on the mobility of ^{99}Tc and Sr (as stable Sr^{2+} at elevated concentrations and $^{90}Sr^{2+}$ at ultra-trace concentrations) under both neutral and alkaline conditions. The reduction of Fe(III) in enrichment culture experiments at an initial pH of 7 or 9 resulted in the precipitation of an Fe(II) bearing biomineral comprised of siderite and vivianite. Results showed that TcO_4^- added at 1.6×10^{-6} M was removed (>80%) from solution concurrent with Fe(III) reduction at both pH 7 and pH 9. Furthermore, X-ray absorption spectroscopy of the reduced biominerals confirmed reduction of Tc(VII) to Tc(IV). To understand Sr behaviour in these systems, Sr^{2+} was added to enrichment cultures at ultra-trace concentrations (2.2×10^{-10} M (as $^{90}Sr^{2+}$)) and at higher concentrations (1.15×10^{-3} M (as stable Sr^{2+})). In ultra-trace experiments at pH 7, microbially active systems showed enhanced removal of ^{90}Sr compared to the sterile control. This was likely due to sorption of $^{90}Sr^{2+}$ to the Fe(II)-bearing biominerals that formed *in situ*. By contrast, at pH 9, the sterile control showed comparable removal of ^{90}Sr to the microbially active experiment even though the Fe-minerals formed were of very different character in the active (vivianite, siderite) versus sterile (an amorphous Fe(III)-phase) systems. Overall, ^{90}Sr bioreduction experiments showed 60–70% removal of the added ^{90}Sr across the different systems: this suggests that treatment strategies involving bioreduction and the promotion of Fe(III)-reducing conditions to scavenge Tc(IV) are not incompatible with treatment of groundwater ^{90}Sr contamination. In systems with elevated Sr^{2+} concentrations and an initial pH of 7, microbially active systems showed <20% removal of added Sr^{2+} following Fe(III) reduction with little or no removal in sterile controls. At pH 9, significant Sr^{2+} was removed from solution in both sterile and microbially active experiments and was attributed to Sr-sorption to mineral phases both chemically precipitated in sterile controls, and biologically precipitated in the microbially active systems. These results confirm that in systems with an elevated natural or anthropogenic Sr^{2+} loading, bioreduction at modestly alkaline pH is compatible with co-treatment of both TcO_4^- and $^{90}Sr^{2+}$. These data are discussed in terms of aqueous geochemistry trends, X-ray diffraction and morphological data, and thermodynamic modelling. The results demonstrate the potential for removal of trace levels of ^{99}Tc and $^{90}Sr^{2+}$ from

groundwaters during stimulated bioreduction and highlight that in the presence of stable Sr^{2+}, optimal removal for technetium and strontium is likely to occur under mildly alkaline, reducing conditions.

14/03212 The Stresa database: a token for the future
Pla, P. *et al. Annals of Nuclear Energy*, 2013, 62, 8–16.
The experimental data recorded in integral effect test facilities (ITFs) are traditionally used in order to validate best estimate (BE) system codes and to investigate the behaviour of nuclear power plants (NPP) under accident scenarios. In the same way, facilities dedicated to specific thermal–hydraulic severe accident (SA) phenomena are used for the development and improvement of specific analytical models and codes used in the SA analysis for light water reactors (LWR). The Joint Research Centre (JRC), Ispra site, of the European Commission has carried out important projects since the 1970s for the production of reactor safety experimental data. The LOBI was a reactor thermal–hydraulic safety research programme (1970–1994) that produced a a great deal of ITF experimental data for a range of PWR operational and accident conditions. In the area of SA, the FARO, KROTOS facilities (1991–2000) simulated Melt fuel coolant interaction phenomena, considering either in-vessel (quenching) and ex-vessel (spreading) experiments and potential situations for steam explosions. The STORM facility simulated experiments in the area of aerosol transport. Experimental data mentioned above were stored in the STRESA (Storage of Thermal REactor Safety Analysis Data) database developed by the JRC Ispra site. At present, the JRC STRESA database is hosted and maintained by JRC Petten site. The paper presents these past activities on the production of experimental data and its storage in the JRC STRESA database in order to further disseminate, promote the usage of the database containing these data and to demonstrate long-term importance of well-maintained experimental databases.

06 ELECTRICAL POWER SUPPLY AND UTILIZATION

Scientific, technical

14/03213 A new method for non-unit protection of power transmission lines based on fault resistance and fault angle reduction
Guo, Z. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 55, 760–769.
A new non-unit transient protection method suitable for single-phase faults of extra high voltage (EHV) power transmission lines was proposed based on the analysis of the propagation characteristics induced by fault transient current, the transition resistance and the fault angle on corresponding energy values of high-frequency transient current in EHV networks. In the procedure, the transient current energy values from both sides of the bus were normalized primarily on the basis of transition resistance and fault angle, and then the characteristic value with functions of direction judge and value comparison was obtained by calculating their difference. By utilizing the characteristic value, the methodology came into being, by which the impacts of both transition resistance and fault angle were eliminated. The overall design has a high reliability level and owns twice the scope of the conventional protection. Simulations were performed and analysed on a three-phase 500 kV power system by utilizing ATP/EMTP, with various kinds of typical faults being taken into account. Plenty of results verify the feasibility of the algorithm for ultra-high speed protection of EHV power transmission lines.

14/03214 A survey of transmission technologies for planning long distance bulk transmission overlay in US
McCalley, J. D. and Krishnan, V. *International Journal of Electrical Power & Energy Systems*, 2014, 54, 559–568.
There is significant interest in building transmission today all over the world, especially inter-regional transmission to interconnect the cheaper renewables which are geographically diverse to load centres. In the USA, the nation's most economically attractive renewable resources are located in the West and Midwest, and most electric consumption is in the East, and a national transmission seems a viable option to supply increasing demand at economical and sustainable manner. This paper presents a short survey of various major electric transmission technologies in terms of their cost and operational characteristics in the context of planning long distance bulk transmission overlay.

14/03215 An energy differential relay for long transmission lines
Wen, M. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 55, 497–502.
The operating speed and sensitivity of the current differential protection must be lowered in order to deal with the problems caused by the capacitive currents of long transmission lines. To solve this problem, a new energy differential relay is put forward. The proposed scheme can distinguish between internal and external faults by comparing the energies of two methods. The first method is to calculate the energy flow in the line in a short time interval. The second method is to calculate the energy consumption of distributed elements on the transmission line with the assumption that there is no internal fault on the line. Special means are adopted: use of modal quantities of voltage and current; the instantaneous voltage and current are distributed linearly along the transmission line; the instantaneous voltage and current vary linearly during a sampling interval; the sampling interval is equal to the travel time of the protected line. Thus, the energies can be calculated by using the sampled values at each end of the transmission line. It has been proven that the calculated energies of the two different methods are equal when there is no internal fault on the transmission line. The performance of the proposed method has been verified by electromagnetic transients program simulation tests, dynamic simulation tests and the comparison with a competitive method.

14/03216 Application of a novel cost reduction index to preventive maintenance scheduling
Mollahassani-pour, M. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 56, 235–240.
Preventive maintenance scheduling of generating units is addressed as a crucial issue that affects both economy and reliability of a power system. In this paper, a new formulation of preventive maintenance scheduling associated with a novel cost reduction index (CRI) is developed. The objective of the cost-based preventive maintenance scheduling consists of the operation as well as maintenance cost over a specified time horizon. A cost reduction index is introduced in such a way to minimize the operation cost while determining the most appropriate maintenance scheme. Here, the proposed framework is structured as a mixed integer linear programming and solved using CPLEX solver. Several analyses are conducted to investigate the impacts of CRI on maintenance scheme as well as system expenditures. The IEEE reliability test system is utilized to demonstrate the effectiveness of the proposed structure and simulation results are promising.

14/03217 Artificial immune systems applied to the reconfiguration of electrical power distribution networks for energy loss minimization
de Oliveira, L. W. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 56, 64–74.
This paper presents a methodology for the reconfiguration of radial electrical distribution systems based on the bio-inspired meta-heuristic artificial immune system to minimize energy losses. The proposed approach can handle this combinatorial mixed integer problem of non-linear programming. Radiality and connectivity constraints are considered as well as different load levels for planning the system operation. For this purpose, improvements to an algorithm in the literature are proposed to better accommodate the features of the problem and to improve the search process. The algorithm developed is tested in well-known distribution systems.

14/03218 Combined operation of SVC and optimal reclosing of circuit breakers for power system transient stability enhancement
Sadi, M. A. H. and Ali, M. H. *Electric Power Systems Research*, 2014, 106, 241–248.
This paper proposes the coordinated operation of optimal reclosing of circuit breakers and a static var compensator (SVC) for enhancing the transient stability of a multi-machine power system. The transient stability performance of the combined operation of optimal reclosing of circuit breakers and SVC is compared with that of the combined operation of conventional reclosing of circuit breakers and SVC. The total kinetic energy of the generators in the system is used to determine the transient stability enhancement index. Simulations are performed through Matlab/Simulink software. Simulation results for both the three-line-to-ground and single-line-to-ground permanent faults at different points of the power system indicate that the proposed combination of optimal reclosing of circuit breakers and SVC can enhance the transient stability of the system well. Also, the

performance of the proposed method is better than that of the combined operation of conventional reclosing of circuit breakers and SVC.

14/03219 Distributed generation support for voltage regulation: an adaptive approach

Kechroud, A. *et al. Electric Power Systems Research*, 2014, 107, 213–220.

Distributed generation (DG) is expected to introduce additional issues in the operation of distribution networks. Among these, voltage variation is of particular concern and needs to be addressed concisely. Conventionally, voltage regulators are placed in transmission level, where they use reactive power control to alter voltage levels. This approach has been particularly effective due to the inductive nature of transmission networks. However, seen from that point of view, distribution networks are different. Hence, this paper introduces a new methodology to address the problem of DG units dispatch while maintaining voltage levels within desired levels. This approach, termed identification-based adaptive voltage regulation (I-BAVR), uses real-time identification of the Thevenin equivalent circuit of the system, giving the X/R ratio to identify the active and reactive power dispatch of the DG unit. The I-BAVR approach has been validated though several steady-state and dynamic simulation scenarios on a typical medium voltage network. These simulations show that by using an appropriate control strategy, DG can regulate the voltage to the specified levels by adapting the amounts of it active and reactive power to the systems operational changes.

14/03220 Distributed voltage control strategy for LV networks with inverter-interfaced generators

Caldon, R. *et al. Electric Power Systems Research*, 2014, 107, 85–92.

Low-voltage (LV) distribution networks are characterized by an ever-growing diffusion of single-and three-phase distributed generators whose unregulated operation may deplete the power quality levels, in particular as regard to voltage profiles and unbalances. This issue is at present under discussion by several national and international standardization bodies and the general trend is to require, for the new connections of generators to medium- and low-voltage grids, their participation to the reactive power network management. In this paper, a novel strategy proposes to control the network voltage unbalance suitably for coordinating single- and three-phase inverter interfaced embedded generators, concurrently with a local volt/var regulation action as foreseen by the new grid connection requirements. Simulations conducted on case study network representing a typical Italian four-wire LV distribution system under different load/generation conditions, demonstrate that the coordinated action of single- and three-phase inverters may considerably reduce the degree of unbalance thus improving the network power quality levels.

14/03221 Drivers and barriers to rural electrification in Tanzania and Mozambique – grid-extension, off-grid, and renewable energy technologies

Ahlborg, H. and Hammar, L. *Renewable Energy*, 2014, 61, 117–124.

Mozambique and Tanzania are countries with very low rural electrification (RE) rates as only about 5% of the rural population use electricity. Despite efforts to extend the national grid in rural areas, most remote areas will not be reached within the foreseeable future. Off-grid (decentralized) electricity grids are seen as a complement and forerunner to the national grid, making electricity available many years in advance and creating demand and a customer base. Renewable energy sources are plentiful in the region and may be particularly useful for off-grid systems. The countries' power sectors are undergoing interesting changes with potential to speed up the pace of RE. However, there are significant barriers to effective RE by grid-extension and off-grid installations. In this study, the specific drivers and barriers for RE in Mozambique and Tanzania are explored across a spectrum of involved actors. By qualitative methodology, drivers and barriers were first identified through literature survey, then data were collected both in semi-structured interviews carried out with power sector actors from national to local level and in visits to off-grid electricity users in Tanzania and Mozambique during eight weeks in 2010. Findings illustrate generic, country-specific, and renewable-energy-technology-specific drivers and barriers to grid and off-grid rural electrification, as perceived by different power sector actors. Results were validated and discussed with three external specialists. Drivers and barriers strongly relate to the roles of national and local actors in planning and implementation. The main drivers are political ambitions based on expected growth of demand, but bottom-up drivers such as local initiatives by industries or churches also exist. The barriers are related to lack of access to human capital, to difficulties in planning and donor dependency, to low rural markets and little interest from private sector, and to more straightforward technical matters such as difficulties with installing electric equipment in traditional buildings. Although off-grid systems and renewable energy sources are recognized by the actors, specific barriers to these systems are related to young organizations responsible for implementation and to guilt-by-association with dysfunctional diesel-based off-grid systems.

14/03222 Dynamic thermal analysis of underground medium power cables using thermal impedance, time constant distribution and structure function

Chatziathanasiou, V. *et al. Applied Thermal Engineering*, 2013, 60, (1–2), 256–260.

The thermal behaviour of a laboratory model for an underground cable has been investigated experimentally. Temperatures are recorded as a function of time so that the dynamic thermal properties could be investigated. The results are represented by thermal impedances. Two new representations, the thermal time constant distribution and the structure functions, will be introduced as well. It will be shown that with the help of a simple analytical model a lot of new information can be gained.

14/03223 Effects of load-following operational methods on combined heat and power system efficiency

Smith, A. D. and Mago, P. J. *Applied Energy*, 2014, 115, 337–351.

Combined heat and power (CHP) systems can be operated in partial loading situations when the maximum electrical and thermal output of the prime mover is not constantly required by the facility. Two basic load-following methods following the thermal load (FTL) and following the electric load (FEL), are compared with a hybrid method which either follows the thermal or the electric demand in a given time period, within a specified operating range, in order to minimize the amount of excess electrical or thermal energy produced by the CHP system. These methods are implemented on an hour-by-hour basis for a large hotel benchmark building which is modelled in 16 cities located in different climate zones using EnergyPlus building simulation software. The hybrid method results in a higher total CHP system efficiency than either the FTL or FEL methods, with CHP system efficiency values from 71% to 87%. The power-to-heat ratio of the building (PHR_b), which describes the relationship between electrical and thermal demand for the given facility, is found to predict the maximum possible CHP system efficiency using the hybrid method on an hourly basis. Buildings with lower PHR_b values, corresponding to higher relative thermal demands, have the highest possible CHP system efficiency values. The hybrid operational method is also implemented on a monthly basis, where the building's average monthly demands are used to set the operating condition of the prime mover for the entire month. The building is then simulated on an hour-by-hour basis to determine the system's performance with only monthly changes in the loading conditions. This monthly method produces similar results to the hybrid method when it is implemented on an hourly basis, with CHP system efficiency values from 74% to 86%.

14/03224 Estimating the potential of controlled plug-in hybrid electric vehicle charging to reduce operational and capacity expansion costs for electric power systems with high wind penetration

Weis, A. *et al. Applied Energy*, 2014, 115, 190–204.

Electric power systems with substantial wind capacity require additional flexibility to react to rapid changes in wind farm output and mismatches in the timing of generation and demand. Controlled variable-rate charging of plug-in electric vehicles allows demand to be rapidly modulated, providing an alternative to using fast-responding natural gas plants for balancing supply with demand and potentially reducing costs of operation and new plant construction. This study investigates the cost savings from controlled charging of electric vehicles, the extent to which these benefits increase in high wind penetration scenarios, and the trade-off between establishing a controlled charging programme vs increasing the capacity of generators in the power system. A mixed integer linear programming model was constructed for capacity expansion, plant dispatch, and plug-in hybrid electric vehicle (PHEV) charging based on the New York independent system operator system. It was found that controlled charging cuts the cost of integrating PHEVs in half. The magnitude of these savings is ~5–15% higher in a system with 20% wind penetration compared to a system with no wind power, and the savings are 50–60% higher in a system that requires capacity expansion.

14/03225 Experimental study of a domestic thermoelectric cogeneration system

Zheng, X. F. *et al. Applied Thermal Engineering*, 2014, 62, (1), 69–79.

Thermoelectric application for power generation does not appear to be appealing due to the low conversion efficiency given by the current commercially available thermoelectric module. This drawback inhibits its wide application because of the overall low thermal efficiency delivered by typical thermoelectric applications. This paper presents an innovative domestic thermoelectric cogeneration system which overcomes this barrier by using available heat sources in domestic environment to generate electricity and produce preheated water for

home use. This system design integrates the thermoelectric cogeneration to the existing domestic boiler using a thermal cycle and enables the system to utilize the unconverted heat, which represents over 95% of the total absorbed heat, to preheat feed water for domestic boiler. The experimental study, based on a model scale prototype which consists of oriented designs of heat exchangers and system construction configurations. An introduction to the design and performance of heat exchangers is provided and a theoretical modelling for analysing the system performance has been established for a good understanding of the system performance at both the practical and theoretical level. Insight has also been provided on the measurements of the parameters that characterize the system performance under steady heat input. Finally, the system performance including electric performance, thermal energy performance, hydraulic performance and dynamic thermal response are introduced.

14/03226 Fault response of inverter interfaced distributed generators in grid-connected applications

Plet, C. A. and Green, T. C. *Electric Power Systems Research*, 2014, 106, 21–28.

Inverter-interfaced distributed generation is prominent in some distribution networks because of the growth of photovoltaic and other new sources. In order to ensure that protection system design remains effective in this environment, it is essential to be able to accurately represent inverters in fault current calculations. Calculating the fault current contribution is complicated because of the nature of the transition into current limiting mode and because the current produced is a function of control choices as well as physical components. The desire is for a simple source plus impedance model for incorporation into network studies. Based on knowledge of the control strategy and the details of the method of current limiting, linear analytical equivalent models are proposed whose source and impedance values (at fundamental frequency) can be expressed as a function of the inverter's hardware parameters and controller gains. The dependence of the entry into current limit on the nature and location of other generators in the network leads to a proposal for a load flow based fault analysis incorporating the new models. This iteratively determines which inverter experiences current limiting. The proposed inverter fault models and their use in a network fault analysis have been verified against experimental results in a three-inverter network.

14/03227 Impacts of intermittent sources on the quality of power supply: the key role of reliability indicators

Drouineau, M. *et al. Applied Energy*, 2014, 116, 333–343.

The reliability of power supply, defined as the ability to recover a steady-state condition after a sudden disturbance, is crucial for operating power systems. It is usually ensured by controlling voltage and frequency deviations and involves events occurring from a few milliseconds to a few hours. However, reliability requirements are largely ignored when dealing with long-term issues. To reconcile such contrasting timescales, it seems logical to rely on energy considerations based on thermodynamics. Two reliability indicators, assessing the magnetic and kinetic energy reserves of a power system, are derived from this approach. They enable to quantify the reliability of a given production mix and make it possible to choose between increasing shares of intermittent sources and maintaining an expected level of reliability. Since the indicators tackle reliability issues without focusing on a specific timescale, they are effective for both discussing the long-term evolution of reliability and improving the real-time management of a power system.

14/03228 Integrated fluid dynamics-process modelling of a coal-fired power plant with carbon capture

Edge, P. J. *et al. Applied Thermal Engineering*, 2013, 60, (1–2), 456–464.

Oxyfuel combustion, where fuel is combusted in a mixture of pure oxygen and recycled flue gases instead of air, is one of the leading options for carbon capture from coal-fired power plants. Accurate simulation of the operation of such plants is critical for the successful development of the technology. A major challenge of such a simulation is how to account for the fundamental differences in gaseous physical and thermal properties; in particular the radiative and convective heat transfer coefficients. In this paper a combined computational fluid dynamics (CFD)–process approach is developed where a detailed CFD model is used to represent the complex gas-phase combustion and radiative heat transfer to the furnace walls and the radiant section of the boiler. This is then combined with a full plant process simulation which includes modifications to the heat transfer components to account for differing gas compositions. The novel integrated calculations have been completed for air-firing and for oxyfuel under a range of conditions and a comparison reveals that there is a possible 'working range' of oxygen concentrations/recycle ratios under which the distribution of heat transfer in the system is similar to air firing and hence the steam conditions can be controlled to set-point temperatures and flows.

14/03229 Loss minimization techniques used in distribution network: bibliographical survey

Kalambe, S. and Agnihotri, G. *Renewable and Sustainable Energy Reviews*, 2014, 29, 184–200.

A distribution system provides a link between the high-voltage transmission system and the low-voltage consumers, thus I^2R loss in a distributed system is high because of low voltage and high current. Distribution companies (DISCOs) have an economic enticement to reduce losses in their networks. Usually, this enticement is the cost difference between real and standard losses. Therefore, if real losses are higher than the standard ones, the DISCOs are economically penalized or if the opposite happens, they obtain a profit. Thus, the loss minimization problem is a well-researched topic and all previous approaches vary from each other by the selection of the tools for loss minimization and thereafter either in the problem formulation or problem solution methods employed. Many methods of loss reduction exist, such as feeder reconfiguration, capacitor placement, high-voltage distribution system, conductor grading, distributed generator allocation, etc. This paper gives a bibliographical survey, general background and comparative analysis of three most commonly used techniques: (i) capacitor placement, (ii) feeder reconfiguration and (iii) distributed generator allocation for loss minimization in distribution networks based on over 147 published articles, so that new researchers can easily find literature particularly in this area.

14/03230 Loss reduction and loadability enhancement with DG: a dual-index analytical approach

Hung, D. Q. and Mithulananthan, N. *Applied Energy*, 2014, 115, 233–241.

The high penetration of distributed generation (DG) is a new challenge for traditional distribution systems. Power injections from DG units change network power flows, thereby influencing system losses and voltage stability. This paper presents a new multi-objective index (IMO)-based analytical approach to determine the optimal size and power factor of DG unit for reducing power losses and enhancing loadability. This index is defined as a combination of active and reactive power loss indices by optimally assigning a weight to each index such that the IMO can reach a minimum level. At this level, the optimal location and weights are identified. The proposed methodology has been tested on three typical distribution systems with different characteristics and validated using an exhaustive load flow solution. The results show that DG operation with optimal power factor and appropriate weights for active and reactive power losses can significantly reduce power losses and enhance loadability.

14/03231 Maximum loadability consideration in droop-controlled islanded microgrids optimal power flow

Abdelaziz, M. M. A. and El-Saadany, E. F. *Electric Power Systems Research*, 2014, 106, 168–179.

An important consideration in the operation of droop-controlled islanded microgrid (IMG) systems is its maximum loadability. This paper proposes the consideration of the system maximum loadability in droop-controlled IMGs optimal power flow (OPF) problems. Three droop-controlled IMG OPF problems are investigated: (1) the OPF problem for maximum loadability assessment, (2) the OPF for maximizing system loadability and (3) the bi-objective OPF problem for loadability maximization and generation cost minimization. A detailed microgrid model is adopted to reflect the special features and operational characteristics of droop-controlled IMG systems in the proposed OPF problems formulations. Numerical simulation studies have been carried out to demonstrate the importance and consequences of considering the system maximum loadability in the operational planning of droop-controlled IMGs.

14/03232 Mismatch losses in PV power plants

Lorente, D. G. *et al. Solar Energy*, 2014, 100, 42–49.

In this paper, two different photovoltaic (PV) arrays have been simulated in order to quantify the electrical mismatch loss in each one of them. The simulations have been performed both in the standard condition and in the dynamic conditions which implement the meteorological data from the two different locations. Two methods have been applied to calculate the mismatch losses. The first one (the simplified method) assumes that all modules are at the tolerance limit and the second one (the *I–V* curve method) calculates the loss instead from the *I–V* characteristic of the modules or of the module series/parallel. Also an ordering procedure starting from the I_{mp} value of the module has been evaluated. The results show a very small mismatch loss in the small PV plant of 40 modules, furthermore the ordering does not influence so much the loss in this case. Instead, the loss in the larger array of 320 modules is bigger and the ordering method presents a more significant influence.

14/03233 Morphological filter applied in a wireless deadbeat control scheme within the context of smart grids

Costa, F. F. *et al. Electric Power Systems Research*, 2014, 107, 175–182.

This paper proposes a digital morphological filter to be applied on reference signals for a deadbeat control of a doubly fed induction generator. The signals are wireless-transmitted from a remote operation centre and prone to be corrupted by spikes caused by a wireless fading channel. The proposed technique filtering and the control scheme are to be implemented in a microprocessor locally placed at the generator site. The filter acts on the signals at the receiving end of the channel and its outputs serves as clean references to the deadbeat control. In order to evaluate the filter performance, corrupted signals have been generated by means of a simulated channel linking the remote centre and the induction generator. The results show the method is efficient in filtering out the spikes without provoking excessive delays.

14/03234 Multi-objective optimization of coal-fired power plants using differential evolution

Wang, L. *et al. Applied Energy*, 2014, 115, 254–264.

The design trade-offs between thermodynamics and economics for thermal systems can be studied with the aid of multi-objective optimization techniques. The investment costs usually increase with increasing thermodynamic performance of a system. In this paper, an enhanced differential evolution with diversity-preserving and density-adjusting mechanisms, and a newly proposed algorithm for searching the decision space frontier in a single run were used, to conduct the multi-objective optimization of large-scale, supercritical coal-fired plants. The uncertainties associated with cost functions were discussed by analysing the sensitivity of the decision space frontier to some significant parameters involved in cost functions. Comparisons made with the aid of an exergoeconomic analysis between the cost minimum designs and a real industrial design demonstrated how the plant improvement was achieved. It is concluded that the cost of electricity could be reduced by a 2–4%, whereas the efficiency could be increased by up to two percentage points. The largest uncertainty is introduced by the temperature-related and reheat-related cost coefficients of the steam generator. More reliable data on the price prediction of future advanced materials should be used to obtain more accurate fronts of the objective space.

14/03235 Novel fault location methods for ungrounded radial distribution systems using measurements at substation

Xiu, W. and Liao, Y. *Electric Power Systems Research*, 2014, 106, 95–100.

This paper describes novel fault location algorithms for ungrounded radial power distribution systems utilizing voltage and current measurements at substation. Two types of fault location approaches, using line to neutral or line to line measurements, are presented. It is assumed that network structure and parameters are known, so that the during-fault bus impedance matrix of the system can be derived. Then node voltages at substation can be expressed as a product of bus impedance matrix and current injection at substation, from which fault location can be estimated. Evaluation studies based on a 16-bus ungrounded radial distribution system have been performed and it has been demonstrated that accurate fault location estimates can be achieved by both types of methods.

14/03236 Optimal sizing of battery energy storage for micro-grid operation management using a new improved bat algorithm

Bahmani-Firouzi, B. and Azizipanah-Abarghooee, R. *International Journal of Electrical Power & Energy Systems*, 2014, 56, 42–54.

In recent years, due to the large integration of renewable energy sources (RESs) such as wind turbines and photovoltaic units into the microgrid (MG), the necessity of battery energy storage (BES) has increased dramatically. BES has several benefits and advantages in the MG-based applications such as short-term power supply, power quality improvement, facilitating integration of RES, ancillary service and arbitrage. This paper presents the cost-based formulation to determine the optimal size of the BES in the operation management of MG. Also, some restrictions, i.e. power capacity of distributed generators, power and energy capacity of BES, charge/discharge efficiency of BES, operating reserve and load demand satisfaction should be considered as well. The suggested problem is a complicated optimization problem, the complexity of which is increased by considering the above constraints. Therefore, a robust and strong optimization algorithm is required to solve it. This paper proposes a new evolutionary technique named improved bat algorithm that is used for developing corrective strategies and to perform least cost dispatches. The performance of the approach is evaluated by one grid-connected low voltage MG where the optimal size of BES is determined professionally.

14/03237 Probability analysis of distributed generation for island scenarios utilizing Carolinas data

Gooding, P. A. *et al. Electric Power Systems Research*, 2014, 107, 125–132.

A distribution system in the Carolinas power grid is modelled to include distributed generation and islanding capacity to create a self-supporting isolation capability. Probability analysis in the form of probability density functions for renewable resources is explained and detailed. The operating conditions within the system are defined using the generation levels of the renewable generation. These operating conditions are then interpreted through the probability analysis. Using these techniques, some of the most relevant results of the study are presented and conclusions are drawn regarding the usefulness of the results. This includes a progressive analysis that covers time periods from seasons to hours, and how these analyses could be utilized by system operators.

14/03238 Proper sizing and placement of distributed power generation aids the intentional islanding process

Shahmohammadi, A. and Ameli, M. T. *Electric Power Systems Research*, 2014, 106, 73–85.

Blackouts occur in power networks after cascading failures which separate the network into some uncontrolled islands. These unintentional islands are mostly faced with a deficiency in active or reactive power balance leading to continuing failures and blackouts. Intentional or controlled islanding is one of the best solutions for preventing blackouts during cascading failures. Controlled islanding strategies can be based on different network features such as its topology and distribution of resources in a way that the imposed amount of load shedding will be minimized. Nowadays, the application of distributed generation (DG) units is increasing rapidly and such units can play a significant role in the process of intentional islanding. In this study, a method for proper sizing and placement of DG units in order to aid the intentional islanding process by strengthening the static stability of newly created islands and minimizing the amount of imposed load shedding was analysed. The proposed method was applied on an IEEE 39-bus network. Simulation results demonstrated the ability and efficiency of proper sizing and placement of DG units from an intentional islanding point of view.

14/03239 Reliability centered maintenance optimization for power distribution systems

Yssaad, B. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 55, 108–115.

Today's electricity distribution systems operate in a liberalized market. These systems should therefore be able to provide electricity to customers with a high degree of reliability and be cost-effective for suppliers. Reliability centred maintenance (RCM) was invented by the aircraft industry in the 1960s to organize the increasing need for maintenance for reducing costs without reducing safety. Today RCM methods are seen as very complex and are not fully accepted by the Algerian power industry. The extensive need of human and capital resources in the introduction phase is also a negative factor that could be one of the reasons of why RCM methods are not used in this branch. This paper provides a discussion of the two primary objectives of RCM: to ensure safety through preventive maintenance actions, and, when safety is not a concern, preserve functionality in the most economical manner. For the power distribution systems facilities, the mission should be considered at the same level as safety.

14/03240 Review of maturing multi-megawatt power electronic converter technologies and reliability modeling in the light of subsea applications

Vedachalam, N. *et al. Applied Ocean Research*, 2014, 46, 28–39.

The increasing demand for establishing deep water enhanced oil recovery systems for subsea boosting, power generation, transmission from remote subsea marine current turbine farms, efficient power transmission and operation of subsea dredgers and mining machines requires subsea based power conversion, as the subsea pumps, compressors and turbines need to be operated at varying power and voltage levels. Even though techno-economic studies indicate the absolute need for locating the multi megawatt power electronic converters in subsea, the recorded failure-in-time data of multi-megawatt capacity industrial standard power converters are not encouraging. Reliability is the key factor, as subsea breakdowns lead to huge production losses, and system retrieval for repair and maintenance is very costly and time consuming. This paper reviews the present technical maturity of a typical industry standard 6 MW capacity 6.6 kV three-level voltage source inverter based power electronic frequency converter, and describes a reliability model in the light of their use in subsea environments. Reliability modelling is done for different possible configurations, with mean time between failure as the driver. The results presented can be directly used by the system designers to select a suitable configuration based on the mean time between failure requirements. The results obtained provide confidence that a suitably configured multi-megawatt power converter, when used in an oil filled enclosure in a deep water environment, could have a mean time between failure of more than 20 years.

14/03241 Review of supporting scheme for island power system storage

Rious, V. and Perez, Y. *Renewable and Sustainable Energy Reviews*, 2014, 29, 754–765.

This paper proposes a support mechanism for energy storage devices for island power systems where intermittent renewable generation is growing rapidly. The authors base their proposal on the maturity level of storage devices and on the linear model for the development of innovations. They focus on storage technologies that can be developed technically in island power systems and that achieve the technical needs of these systems. The authors recommend the adoption of a feed-in tariff with the price varying with the time of day to push for the deployment of power storage avoiding the curtailment of massive intermittent renewable generation.

14/03242 Scalable preparation of three-dimensional porous structures of reduced graphene oxide/cellulose composites and their application in supercapacitors

Ouyang, W. *et al. Carbon*, 2013, 62, 501–509.

Controlling the assembled structures of graphene has recently attracted enormous attention due to intriguing properties of the resultant structures. In this study, three-dimensional (3D) porous structures of reduced graphene oxide (RGO) with various ratios of RGO to cellulose have been fabricated by a scalable, but simple and efficient, approach that consists of ball-milling-assisted chemical reduction of graphene oxide, template shaping, coagulating and lyophilization. The efficient mechanical shearing of ball milling and the hydrogen bond interactions between RGO and cellulose molecules contribute to the formation of a homogeneous RGO/cellulose hydrogel, improved thermal stability of the resultant composites, and enhanced crystallinity of the cellulose in the composites. The coagulation effect of cellulose maintains the RGO sheets in the 3D structures of cellulose; on the other hand, the RGO sheets facilitate the preservation of the 3D structures during freeze-drying, leading to the formation of 3D porous structures of RGO/cellulose composites. Benefiting from the continuous RGO network in the composites, the 3D porous structures of RGO(70)/cellulose(100) (GO : cellulose = 70 : 100 in weight) show an electrical conductivity of 15.28 $S\,m^{-1}$. Moreover, the 3D porous structures show potential application in supercapacitors due to the fact that they provide high specific surface area and fast charge propagation.

14/03243 System modeling and optimization for islanded micro-grid using multi-cross learning-based chaotic differential evolution algorithm

Hemmati, M. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 56, 349–360.

This paper presents a comprehensive operation model for microgrids (MG) operating in the islanded mode. Various energy sources of a MG including diesel engine generator, micro-turbine, wind turbine and photovoltaic cell as well as battery storage and AC/DC rectifier/inverter are modelled in the proposed framework. Fuel costs, emission costs, and operation and maintenance costs of these sources as well as their operating limits and characteristics are considered in the model. Furthermore, a new multi-cross learning-based chaotic differential evolution algorithm is presented to solve the optimization problem of MG operation. The numerical results obtained from the proposed solution approach for three MG test cases with real-world data are compared with the results of several other recently published optimization methods. These comparisons confirm the validity of the developed approach.

14/03244 Thermal conductivity and temperature profiles in carbon electrodes for supercapacitors

Burheim, O. S. *et al. Journal of Power Sources*, 2014, 246, 160–166.

The thermal conductivity of supercapacitor film electrodes composed of activated carbon (AC), AC with 15 mass% multi-walled carbon nanotubes (MWCNTs), AC with 15 mass% onion-like carbon (OLC), and only OLC, all mixed with polymer binder (polytetrafluoroethylene), has been measured. This was done for dry electrodes and after the electrodes have been saturated with an organic electrolyte (1 M tetraethylammonium–tetrafluoroborate in acetonitrile, TEA–BF_4). The thermal conductivity data was implemented in a simple model of generation and transport of heat in a cylindrical cell supercapacitor systems. Dry electrodes showed a thermal conductivity in the range of 0.09–0.19 $W\,K^{-1}\,m^{-1}$ and the electrodes soaked with an organic electrolyte yielded values for the thermal conductivity between 0.42 and 0.47 $W\,K^{-1}\,m^{-1}$. It was seen that the values related strongly to the porosity of the carbon electrode materials. Modelling of the internal temperature profiles of a supercapacitor under conditions corresponding to extreme cycling demonstrated that only a moderate temperature gradient of several degrees Celsius can be expected and which depends on the ohmic resistance of the cell as well as the wetting of the electrode materials.

14/03245 Thermal power plant efficiency enhancement with ocean thermal energy conversion

Soto, R. and Vergara, J. *Applied Thermal Engineering*, 2014, 62, (1), 105–112.

In addition to greenhouse gas emissions, coastal thermal power plants would gain further opposition due to their heat rejection distressing the local ecosystem. Therefore, these plants need to enhance their thermal efficiency while reducing their environmental offense. In this study, a hybrid plant based on the principle of ocean thermal energy conversion was coupled to a 740 MW coal-fired power plant project located at latitude 28°S where the surface to deepwater temperature difference would not suffice for regular OTEC plants. This paper presents the thermodynamical model to assess the overall efficiency gained by adopting an ammonia Rankine cycle plus a desalinating unit, heated by the power plant condenser discharge and refrigerated by cold deep seawater. The simulation allowed us to optimize a system that would finally enhance the plant power output by 25–37 MW, depending on the season, without added emissions while reducing dramatically the water temperature at discharge and also desalinating up to 5.8 million tons per year. The supplemental equipment was sized and the specific emissions reduction was estimated. The authors believe that this approach would improve the acceptability of thermal and nuclear power plant projects regardless of the plant location.

14/03246 Use of model predictive control for experimental microgrid optimization

Parisio, A. *et al. Applied Energy*, 2014, 115, 37–46.

This study deals with the problem of efficiently optimizing microgrid operations while satisfying a time-varying request and operation constraints. Microgrids are subsystems of the distribution grid comprising sufficient generating resources to operate in isolation from the main grid, in a deliberate and controlled way. The model predictive control (MPC) approach is applied for achieving economic efficiency in microgrid operation management. The method is thus applied to an experimental microgrid located in Athens, Greece. The experimental results have shown that that this MPC-mixed integer linear programming control scheme is able to optimize economically the microgrid operations and save money compared to the current practice; the cost is addressed and parameterized in detail in the problem formulation so to take advantage of the economic benefits of the distributed energy resources. The experiments have also evidenced how allowable curtailments can be performed and a trade-off between demand peak reduction and user comfort can be achieved. Future work will focus on including state estimation and reactive power management in the control scheme. Further extensions of the presented study will include a sensitivity analysis of the optimization model's parameters; for instance, critical parameters are the number of battery cycles and the battery capacity, which are largely affected by the operation profile.

14/03247 Using coolant modulation and pre-cooling to avoid turbine blade overheating in a gas turbine combined cycle power plant fired with low calorific value gas

Kwon, I. H. *et al. Applied Thermal Engineering*, 2013, 60, (1–2), 285–294.

Overheating of turbine blades is one of the major concerns in using low calorific value fuels in gas turbines. This work examined the deviation of operating conditions of a gas turbine fired with a low calorific value gas fuel, with a focus on the turbine blade temperatures. Several measures to suppress blade overheating were compared in terms of the power output and efficiency of the gas turbine combined cycle plant. Blade overheating can be prevented by decreasing the firing temperature without the need for hardware modifications, but the accompanying power reduction is considerable. As a remedy to this large reduction in power, modulation of the coolant supply to each blade row was simulated, and a much lower power penalty was observed. Moreover, pre-cooling of the coolant enhances the power output further by reducing the coolant supply. Pre-cooling recovers 80% of the available maximum augmentation of the combined cycle by simply switching the fuel from natural gas to low calorific value gas. Pre-cooling also provides higher overall combined cycle efficiency compared to under-firing.

Economics, policy, supplies, forecasts

14/03248 A hybrid economic indices based short-term load forecasting system

Lin, C.-T. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 54, 293–305.

The bankruptcy of Lehman Brothers and the corresponding global economic recession in 2008 and 2009 influenced the electricity load demand patterns for which traditional load forecasting approaches

were not able to effectively predict. To overcome this problem, this paper proposes a new hybrid economic indices based short-term load forecasting (HEI-STLF) system. In which business indicators, such as the leading index or the coincide index, each combined with stock index as hybrid economic indices influencing factors for the support vector regression (SVR) model, to respond to the economic dynamics and reduce its impact on forecasting accuracy. The Taiwan island-wide electricity load demands from 2008 to 2011 are used as the case study for performance testing with different combinations of the Taiwan business indicator and the Taiwan Stock Exchange Capitalization-Weighted Stock Index (TAIEX). The results show that the proposed HEI-STLF system with hybrid economic indices of an annualized 6-month rate of change of composite leading index and a 90 days moving average of TAIEX, achieves the best forecasting performance. Compared to the traditional SVR load forecasting approach, it improves the forecasting accuracy in the best condition by 30.39% in the period when the load demands are affected by the global economic recession.

14/03249 A hybrid wavelet-ELM based short term price forecasting for electricity markets

Shrivastava, N. A. and Panigrahi, B. K. *International Journal of Electrical Power & Energy Systems*, 2014, 55, 41–50.

Accurate electricity price forecasting is a formidable challenge for market participants and managers owing to high volatility of the electricity prices. Price forecasting is also the most important management goal for market participants since it forms the basis of maximizing profits. This study investigates the performance of a novel neural network technique called extreme learning machine (ELM) in the price forecasting problem. Keeping in view the risk associated with electricity markets with highly volatile prices, relying on a single technique is not so profitable. Therefore, ELM has been coupled with the wavelet technique to develop a hybrid model termed as WELM (wavelet-based ELM) to improve the forecasting accuracy as well as reliability. In this way, the unique features of each tool are combined to capture different patterns in the data. The robustness of the model is further enhanced using the ensembling technique. Performances of the proposed models are evaluated by using data from Ontario, PJM, New York and Italian electricity markets. The experimental results demonstrate that the proposed method is one of the most suitable price forecasting techniques.

14/03250 A review on sustainable power generation in Malaysia to 2030: historical perspective, current assessment, and future strategies

Khor, C. S. and Lalchand, G. *Renewable and Sustainable Energy Reviews*, 2014, 29, 952–960.

This review considers energy for grid-connected electricity generation for west (peninsular) Malaysia. A historical perspective of Malaysia's energy policies and energy-related initiatives is provided, setting the scene for an assessment of current situation in the country. The authors recommend a number of sustainable options for addressing the projected energy deficits in Malaysia up to year 2030, besides meeting the drive for low carbon systems and technologies. The latter is in direct response to an announcement of a conditional voluntary target of 40% reduction in the emissions intensity per unit of gross domestic product by 2020 from a 2005 baseline at the COP15 (United Nations Climate Change Conference) meeting in Copenhagen. Alternative strategies are suggested that promote enhanced roles for renewable energy (RE) as well as energy efficiency and conservation (EE&C) practices based on a review of past and present policies and current developments. A greater contribution of RE from biomass, biogas, hydroelectric power and solar photovoltaic is proposed compared to the present less than 1%, in concert with continuous more widespread adoption of EE&C initiatives. Strategies are also advocated to improve coal supply reliability and security. On top of these measures, the Malaysian government is urged to moderate energy subsidies while enforcing a common energy regulatory framework that involve all relevant agencies and parties.

14/03251 Adaptive scheme for local prediction of post-contingency power system frequency

Alizadeh, M. and Amraee, T. *Electric Power Systems Research*, 2014, 107, 240–249.

Power system frequency should always be kept above a minimum threshold determined by the limitations of system equipment such as synchronous generators. In this paper, a new method is proposed for local prediction of maximum post-contingency deviation of power system frequency using artificial neural network (ANN) and support vector regression (SVR) learning machines. Due to the change of network oscillation modes under different contingencies, the proposed predictors adjust the data sampling time for improving the performance. For ANN and SVR training, a comprehensive list of scenarios is created considering all credible disturbances. The performance of the proposed algorithm is simulated and verified over a dynamic test system.

14/03252 An efficient automated topology processor for state estimation of power transmission networks

Farrokhabadi, M. and Vanfretti, L. *Electric Power Systems Research*, 2014, 106, 188–202.

A robust network topology processor that can be utilized in both traditional and phasor measurement unit (PMU)-based state estimators is developed. Previous papers in the field of topology processing are scrutinized and their drawbacks are identified. Building on top of the state of the art, an algorithm covering the limitations of available topology processing approaches and including new features is proposed. The presented algorithm was implemented in Matlab and tested using two different power networks with detailed substation configurations (bus/breaker models) including a modified version of the IEEE Reliability Test System 1996. As the topology processor is intended to supply network topologies to a PMU-based state estimator, the IEEE Reliability Test System 1996 is simulated in real-time using the eMegaSim Opal-RT real-time simulator which is part of 'SmarTS Lab' at the KTH Royal Institute of Technology. Testing is carried out through several test scenarios and computation times are calculated. It is shown that the computation times are adequate for supporting a PMU-only state estimator.

14/03253 An interactive building power demand management strategy for facilitating smart grid optimization

Xue, X. *et al. Applied Energy*, 2014, 116, 297–310.

With increasing use and integration of renewable energies, power imbalance between supply and demand sides has become one of the most critical issues in developing smart grid. As the major power consumers at demand side, buildings can actually perform as distributed thermal storages to help relieving power imbalance of a grid. However, power demand alteration potentials of buildings and energy information of grids might not be effectively predicted and communicated for interaction and optimization. This paper presents an interactive building power demand management strategy for the interaction of commercial buildings with a smart grid and facilitating the grid optimization. A simplified building thermal storage model is developed for predicting and characterizing power demand alteration potentials of individual buildings together with a model for predicting the normal power demand profiles of buildings. The simulation test results show that commercial buildings can contribute significantly and effectively in power demand management or alterations with building power demand characteristics identified properly.

14/03254 Construction and analysis of an automatic multirate time domain simulation method for large power systems

Savcenco, V. and Haut, B. *Electric Power Systems Research*, 2014, 107, 28–35.

A multi-rate method for the time-domain simulation of large power systems is presented. Analysis of the proposed multi-rate method shows how the coupling between fast and slow components affects the numerical stability of the method. Numerical results for two power system examples are presented. Comparison with the corresponding standard integration method shows that substantial gain in computational work and computer time can be obtained.

14/03255 Does a detailed model of the electricity grid matter? Estimating the impacts of the Regional Greenhouse Gas Initiative

Shawhan, D. L. *et al. Resource and Energy Economics*, 2014, 36, (1), 191–207.

The consequences of environmental and energy policies in the USA can be severely constrained by physical limits of the electric power grid. Flows do not follow the shortest path but are distributed over all lines in accordance with the laws of physics, so grid operators must select which generation units to operate at each moment, not only to minimize production costs, but also to prevent the system from collapsing because of line overloads. Because of the complexity of power grid operation, computing limitations have until very recently made it impossible to solve a policy analysis or planning model that combines realistic modelling of flows with a detailed transmission system model and the prediction of generator investment and retirement. In this study, the authors construct and solve a model of the eastern USA and Canada that combines these characteristics. Then, because a smaller model would be usable for some additional purposes, they explore the effects of transmission model simplification on the accuracy of simulation results. To evaluate the amount of detail necessary, the authors simulate the short- and long-term effects of imposing a price on the carbon dioxide emissions from the power plants in nine north-eastern US states, as the Regional Greenhouse Gas Initiative does. They consider three grid models that simplify the actual 62,000-node system to varying degrees. The 5000-node model matches the 62,000-node model very closely. This model is then used as the basis for evaluating the more simplified models: a 300-node model and a model with just one node, i.e. no transmission constraints. With

each of the three models, the authors predict the carbon dioxide emission impacts, electricity price impacts, and generator entry and exit impacts of the emission price, over the next 20 years. It was found that most of the impact predictions produced by the 300- and one-node models differ from those of the 5000-node model by more than 20%, and some by much more. Fortunately, the 5000-node model, and others with its combination of transmission detail, realistic flows, entry prediction, and retirement prediction can be used for many useful purposes.

14/03256 Electricity market opening impact on investments in electricity sector

Streimikiene, D. and Siksnelyte, I. *Renewable and Sustainable Energy Reviews*, 2014, 29, 891–904.

This paper considers the impact of the electricity market regulation on generating technologies, including renewables in Lithuania and Poland. The paper aims to identify how regulatory and non-regulatory factors have influenced investors' choices. A country case studies approach was applied to analyse, address and define the main factors that have influenced investors' choice of technology mix in an electricity market that is in transition. The major findings of the analysis are as follows: the main driving forces behind the rationale for reform; electricity reform characteristics; the impact of electricity market reform on electricity prices and electricity market reform and non-reform related factors that have influenced investor's choice for a specific generation technology or a technology mix.

14/03257 Generating renewable energy from oil palm biomass in Malaysia: the feed-in tariff policy framework

Umar, M. S. *et al. Biomass and Bioenergy*, 2014, 62, 37–46.

The renewable energy (RE) industry in Malaysia began in 2001 in the context of the growing concern about future depletion of conventional fuels and the global environmental concerns about greenhouse gas emissions. The Small Renewable Energy Programme is a tool that was first designed to drive the development of the industry based on the abundance of oil palm biomass reserves and other identified renewable energy resources. Due to the slow uptake of this scheme, a new system, the feed-in tariff (FiT) was introduced in 2011 to stimulate the industry. By considering the deficiencies of the previous scheme, this paper examines the sustainability of the FiT policy framework in steering the future expansion of small-scale biomass renewable energy businesses in Malaysia. Resulting from the evaluation of the current policy settings and a market based appraisal, this work suggests the following adjustments: extend the FiT bandwidth capacity restrictions to all of the eligible renewable technologies under the FiT systems; differentiate the tariff level by considering the location and local conditions of the plant site; modify the revenue streams from the renewable fund, and revise the quota system whenever the domestic market is ready to be deregulated or when the FiT mechanism is deemed to be mature. In addition, there are policy areas that require further studies including an evaluation of the socio-economic and environmental (e.g. carbon savings) sustainability of the oil palm biomass downstream value chain particularly with specific attention to the security of resource supply, additional support for technology advancement and a better grid extension system.

14/03258 Optimization models for an EV aggregator selling secondary reserve in the electricity market

Bessa, R. J. and Matos, M. A. *Electric Power Systems Research*, 2014, 106, 36–50.

Power system regulators and operators are creating conditions for encouraging the participation of the demand-side into reserve markets. The electric vehicle (EV), when aggregated by a market agent, holds sufficient flexibility for offering reserve bids. Nevertheless, due to the stochastic nature of the drivers' behaviour and market variables, forecasting and optimization algorithms are necessary for supporting an EV aggregator participating in the electricity market. This paper describes a new day-ahead optimization model between energy and secondary reserve bids and an operational management algorithm that coordinates EV charging in order to minimize differences between contracted and realized values. The use of forecasts for EV and market prices is included, as well as a market settlement scheme that includes a penalty term for reserve shortage. The optimization framework is evaluated in a test case constructed with synthetic time series for EV and market data from the Iberian electricity market.

14/03259 Policies and demonstrations of micro-grids in China: a review

Zeng, Z. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 701–718.

Micro-grids are effective concepts and systems to interface renewable and sustainable energy resources. In this paper, the policies and demonstrations of micro-grids for research and development, as well as practical applications in China, have been reviewed. Many recent policies on renewable energy and micro-grids are summarized, which have been guiding and contributing to the development of micro-grids in China. Additionally, the available demonstration micro-grids in China are also introduced in detail. Finally, the emergency necessaries and trends of micro-grid applications in China have been concluded.

14/03260 Reliability assessment of incentive- and priced-based demand response programs in restructured power systems

Nikzad, M. and Mozafari, B. *International Journal of Electrical Power & Energy Systems*, 2014, 56, 83–96.

Fostering demand response (DR) through incentive-based and priced-based programs has always great impact on improvement of efficiency and reliability of the power systems. The use of DR lowers undesirable effects of failures that usually impose financial costs and inconveniences to the customers. Hence, quantifying the impact of demand response programmes (DRPs) on reliability improvement of the restructured power systems is an important challenge for the independent system operators and the regional transmission organizations. In this paper, the DR model which treats consistently the main characteristics of the demand curve is developed for modelling. In proposed model, some penalties for customers in case of no responding to load reduction and incentives for customers who respond to reducing their loads are considered. In order to make analytical evaluation of the reliability, a mixed integer DC optimal power flow is proposed by which load curtailments and generation re-dispatches for each contingency state are determined. Both transmission and generation failures are considered in contingency enumeration. The proposed technique is modelled in the GAMS software and solved using CPLEX as a powerful mixed integer linear programming solver. Both supply-side reliability for generation companies and demand-side reliability for customers are calculated using this technique. In order to simulate customers' behaviour to different DRPs in a real power network, the proposed DR model is used and evaluated over Iranian power network. In order to investigate the reliability effects of DRPs based on proposed reliability method, DRPs based on the DR model are implemented over the IEEE reliability test system (RTS) 24-bus test system, and reliability indices for generation companies, transmission network and customers are calculated. Using proposed performance index, the priority of the DRPs are determined from view point of customers, generation companies, transmission network and the whole system in IEEE RTS.

14/03261 Risk analysis and management in power outage and restoration: a literature survey

Castillo, A. *Electric Power Systems Research*, 2014, 107, 9–15.

Research on power outage and restoration typically focuses on the risk analysis or the risk management but rarely incorporates both. It has been difficult to apply the methodologies in both types of studies into a single study because there has not been an effective and unanimous approach in how to relate reliability and resiliency to market efficiency and economic losses. Reliability metrics and standards vary significantly in the USA. From an economic perspective, it is not well understood how to make improved reliability and resiliency a fungible asset. Often transmission and generation planning, as well as restoration planning, is requirement driven and must be balanced with factors that drive grid investments. Future work in this area can further address integrating the risk analysis into investment and restoration planning decisions in order to better incorporate grid resilience targets, restoration strategies, the adoption of smart grid techniques, and hardening of critical components.

14/03262 Risk assessment of interruption times affecting domestic and non-domestic electricity customers

Ilie, I.-S. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 55, 59–65.

Legislation defined to protect domestic and non-domestic customers from long durations of electricity supply interruptions includes additional requirements to system's reliability-related performance that distribution network operators (DNOs) must consider in planning the operation and maintenance process of power supply systems. DNOs are required to restore the supply to interrupted customers that fall into 'unprotected' customer class within a given period of time, otherwise penalties are applied. In order to meet these requirements, comprehensive strategies must be defined based on upfront analyses. Accordingly, this paper proposes a deterministic algorithm for estimating DNOs' risk of experiencing interruptions with durations above imposed targets. Besides the regulator-defined legislation, security of supply requirements are engaged in the development of the proposed methodology. Failure analysis of network components is used to identify interrupted customers that are grouped into power demand classes such that the duration of interruptions can be addressed following the security of supply requirements. Moreover, the penalty times defined by the energy regulator are engaged in the analysis and used as thresholds to quantify the penalty risk that DNOs

are exposed to. The proposed methodology is applied to a typical UK distribution system, whose average reliability performance is also considered in the analysis.

14/03263 The present and future of smart power grid in developing countries
Fadaeenejad, M. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 828–834.
Interest in smart grids has increased extensively around the world in recent years. This scenario could be a promising reason for future research in this area. This next form of electricity grid will be able to manage various parts of power production from power plants to the customers. The smart grid has become a major challenge in developed nations in both research and utilization aspects. On the other side, application of smart grids in developing countries is still lagging behind as compared to the developed ones. However, most of developing nations are currently investigating potentials of some pilot projects or few research works. In this paper, the applied activities in developing countries for smart grids are reviewed and categorized into two major groups: pioneer developing countries in smart grids and other developing countries are placed in the other group. The findings demonstrate that a few countries such as China, India and Brazil have had proper planning and development in this technology. In some cases like China, the efforts are considered comparable with developed nations like the USA. Therefore, according to the development progress for smart grids in China, India and Brazil, a pattern of reference for other developing countries is suggested.

14/03264 Using fuzzy logic to model the behavior of residential electrical utility customers
Zúñiga, K. V. *et al. Applied Energy*, 2014, 115, 384–393.
Peaks and valleys affecting the efficiency of the power system can be detected by analysing the load curve. These oscillations are caused by changes in consumer behaviour, mainly consumers in the residential sector. This paper presents the use of fuzzy logic systems to model human behaviour related to activation of appliances and lighting at home. Based on this model, the hourly activation profile for each appliance can be obtained and, subsequently, the load curve of the residential sector can be calculated. This model aims at contributing to the simulation of strategies for demand-side management.

14/03265 Willingness to pay for residential electricity supply quality and reliability
Hensher, D. A. *et al. Applied Energy*, 2014, 115, 280–292.
A key feature of many regulatory reviews is determination of the amount of expenditure that should be reflected in the revenue requirement for a service provider. An increasingly important driver in determining the appropriate level of this expenditure is the desired level of service quality and requisite service targets which are incorporated in the 'regulatory bargain'. Willingness to pay (WTP) evidence can be used in the regulatory bargain to establish such targets. This study examines households' WTP to avoid specific restrictions on service supply quality (especially reliability) in residential electricity, using stated choice experiments to reveal the set of preferences required to calculate WTP. Using a sample of residents in Canberra, Australia, it was found that residential customers value reliability of the electricity service; in particular, frequency and the duration of outages are important to customers, and customers value incurring fewer and shorter outages, compared to more frequent and longer outages. The average WTP to avoid a common set of events such as outages, power surges and flickers in electric current vary from $60 per customer per event for an 8-h electricity outage when it occurs once a year through to $9 per event for a flicker in electric current.

07 STEAM RAISING

Boiler operation/design

14/03266 A novel coal combustion technology for a down-fired boiler: aerodynamic characteristics
Yang, W. *et al. Fuel Processing Technology*, 2014, 118, 90–97.
A new combustion technology, the hot air packing (HAP) technology, was proposed and researched to improve the coal burnout and control NO_x emission in down-fired boilers. Compared with the prior technology, HAP technology necessitates the addition of special secondary air ports added in the furnace ash hopper (SA-H) and the furnace bottom (SA-B). Cold-air-flow experiments in a 1 : 4-scale model and fluid dynamics numerical simulations were carried out to reveal the aerodynamic characteristics in a furnace with HAP technology. The experimental and simulation results coincided well with each other; and both showed that HAP technology had rational aerodynamic characteristics in the furnace. Compared with a base case, common down-fired combustion technology, HAP technology forms a larger W shape and bigger recirculation zones, as well as a larger penetration depth of primary air flow. Moreover, HAP technology destroys the dead recirculation zones and avoids air flow washing against the wall. The angle and location of SA-H have great impacts on the aerodynamic characteristics in the furnace, especially in the ash hopper. Within the six cases, the SA-H configuration with an angle of 0° and the upper-located position yielded optimal results.

14/03267 Comparison of power plant steam condenser heat transfer models for on-line condition monitoring
Saari, J. *et al. Applied Thermal Engineering*, 2014, 62, (1), 37–47.
In this paper heat transfer models for large power plant condenser were examined. The goal was to develop a model capable of predicting not only the condenser pressure but the overall heat transfer coefficient. Such a model can be used for condenser condition monitoring. The results of a two-dimensional (2-D) condenser heat transfer model and single-point, zero-dimensional (0-D) model are presented together with the results from Heat Exchanger Institute (HEI) standards curves. Both 0-D and 2-D models can account for the effects of steam-side pressure drop and in a simplified manner also some effects of tube bundle geometry. For all models an experimental correction as a function of cooling water temperature was implemented to improve their accuracy. The results are presented in comparison with the measured plant data for three different tube bundle geometries, with and without the experimental correction factor. The 2-D model proved to be the most consistently accurate of the models both without the correction, and at varying steam and coolant flow with the correction applied. The results indicate significant local variation of pressure drop related effects, which the 0-D model failed to accurately predict particularly in cases of close temperature approach. In predicting the heat transfer coefficient the HEI model was the least accurate, significantly overestimating the impact of coolant flow rate change, and failing to match the measurements even with a correction applied.

14/03268 Development of a distributed-parameter model for the evaporation system in a supercritical W-shaped boiler
Shu, Z. *et al. Applied Thermal Engineering*, 2014, 62, (1), 123–132.
In this paper, a distributed parameter model of an evaporation system in a supercritical W-shaped once-through boiler is developed based on the three-dimensional temperature distribution. The mathematical model was formulated to predict the distributions of the heat flux and the metal-surface temperature while considering a non-uniform distribution of the surface heat transfer and the frictional resistance coefficient. The results show that the heat flux distribution on the front water wall has three high heat flux zones in the W-shaped boiler, and the peak of the heat transfer coefficient moves to the peak of the heat flux gradually with the increment of load at supercritical pressure. The maximum deviation of the metal temperature is nearly 94 °C for different loads. This distributed parameter model is fit for the *in situ* operating status of the boiler, and it provides a reference for the heat transfer of a supercritical system.

14/03269 Dynamic heat transfer performance study of steam generator based on distributed parameter method
Zhang, G. *et al. Annals of Nuclear Energy*, 2014, 63, 658–664.
Using the steam generator of the Daya Bay nuclear power plant as prototype, a one-dimensional dynamic mathematical model of nuclear-powered steam generator is built addressing the primary side fluid, the secondary side fluid and the inner and outer walls of the U-tubes based on a distributed parameter method and reasonable assumptions. A dynamic simulation program is developed based on MATLAB using the Runge–Kutta method and dynamic heat transfer performance simulation of steam generator is conducted under varying power. The calculation results show that the outlet temperature of primary side, the vapour saturation temperature and the mass fraction of secondary side agree with actual operating data of the Daya Bay plant. The outer wall temperature at the interface between parallel flow preheating-section and boiling-section is the highest. It provides a theoretical basis for the analysis of steam generator actual operating conditions to build a one-dimensional mathematical model of steam generator based on the distributed parameter method and apply in simulation successfully.

14/03270 Effect of condensation temperature glide on the performance of organic Rankine cycles with zeotropic mixture working fluids
Liu, Q. *et al. Applied Energy*, 2014, 115, 394–404.

The organic Rankine cycle (ORC) has been widely used to convert low-grade (<300 °C) thermal energy to electricity. Use of zeotropic mixtures as the working fluids improves the thermodynamic performance of ORC systems due to better matches of the temperature profiles of the working fluid and the heat source/sink. This paper presents a method to determine the optimal ORC condensation pressure when using a zeotropic mixture. This study also investigates the effects of the condensation temperature glide of the zeotropic mixture on the ORC thermodynamic performance. Geothermal water and biomass are used as the heat sources. Zeotropic mixtures of butane/pentane (R600/R601), butane/isopentane (R600/R601a), isobutane/pentane (R600a/R601) and isobutane/isopentane (R600a/R601a) were selected as the working fluids for the geothermal ORC with octane/decane, nonane/decane and octamethyltrisiloxane/decamethyltetrasiloxane (MDM/MD_2M) selected as working fluids for the cogenerative ORC driven by the biomass energy. Two optimal working fluid mole fractions maximize the cycle efficiency, exergy efficiency and net power output for cooling water temperature increases less than the maximum condensation temperature glide, while the highest net power output appears at the higher mole fraction of the more volatile component for the geothermal ORC when the condensation temperature glide of the working fluid mixture matches the cooling water temperature increase. Higher condensation temperature glides result in large thermal loss to the heat sink and exergy destruction in the condenser. There is only one optimal working fluid mole fraction that maximizes the thermal efficiency, exergy efficiency and net power output when the cooling water temperature increase is greater than the condensation temperature glide.

14/03271 Effect of steam-exhaust operation of secondary coolant circuit on ship reactor blackout accident

Yang, L. *et al. Annals of Nuclear Energy*, 2014, 63, 38–45.

A ship reactor blackout accident can potentially lead to a severe accident and radioactive fission product release. In the absence of an auxiliary electrical source, the effective mitigation of the accident aftereffect is very important. As the exclusive heat trap in the reactor coolant system, the steam-exhaust operation (SEO) in the secondary coolant circuit (SCC) plays an important role in accident mitigation. In view of the character of ship nuclear power plant, the ship reactor blackout accident under the typical operating conditions is simulated by the RELAP5/MOD3.2 code, and the mitigation of SEO on the accident is analysed. It was found that (1) reasonable SEO can obviously mitigate the accident for several hours, the SEO with 1% rated steam flux of secondary coolant circuit provides about 7 h for the mitigation of accident, (2) a reduced steam flux of SCC during the SEO means a slower pressure drop of steam generation (SG) and more time for accident mitigation, there are 1.5 h between the SEO with 1% rated steam flux and that with 3% rated steam flux, (3) the SEO without the feed water device can hardly mitigate the accident, and (4) during the blackout accident, the SEO with intercurrent steam flux control valve failure will result in decreased mitigation time because of the quick decrease of SG pressure, but the mitigation effect is also obvious.

14/03272 Scaling modeling analysis of flow instability in U-tubes of steam generator under natural circulation

Hao, J. *et al. Annals of Nuclear Energy*, 2014, 64, 169–175.

It is found that under the natural circulation condition the reverse flow occurs in the U-tubes of steam generator (SG), which has large influence on the reactor safety. Though the reverse flow in SG is thought as the Ledinegg-type flow instability that is dominated by the flow resistance and gravitation pressure drop, it has not been studied well. Because of the complexity of the problem and the limitation of research conditions, it is a good way to perform the numerical simulation based on the scaling model. In the present work, based on one-dimensional N–S equations, the flow instability in U-tubes is investigated and the flow instability criterion (critical Reynolds number) is derived. The flow and heat transfer in the plenums and pipes are modelled by three-dimensional conservation equations. Using the integral analogy method, a set of scaling modelling criteria are also obtained, and the scaling modelling conditions in the stream generator primary side are given by the similar second theorem. The applicability of these conditions is discussed. The results can be used as the basic of the numerical simulation of the flow instability in U-tubes of SG.

14/03273 Slagging in PC [pulverized coal] boilers and developing mitigation strategies

Bilirgen, H. *Fuel*, 2014, 115, 618–624.

Excessive slagging in coal-fired boilers on heat transfer surfaces such as water wall tubes, lower regions of the finishing superheater and superheater areas on the slope of the nose region was investigated for a pulverized coal-fired boiler that is forced to burn off-design coal. A detailed coal and ash analyses was carried out to understand the root cause problem. Slagging mitigation strategies involving boiler operations and cleaning methods were developed and implemented. Coals from two identical boilers, one with excessive slagging (boiler A) and the other (boiler B) with no slagging, were compared to understand the root cause problem. Detailed coal and ash analyses have shown a high iron content in ash as pyrite (FeS_2), which has historically been known to promote boiler slagging. Computer-controlled scanning electron microscopy analyses revealed that the pyrite was present in relatively coarse size fractions. If not pulverized well in the pulverizers, this coarse pyrite can result in low melting phases, because complete oxidation to a higher melting point oxide cannot be achieved. Ash fusion temperatures of ashes were found to be in the 2000–2500 °F range, with an average ash softening temperature in an oxidizing atmosphere of 2360 °F. Furnace exit gas temperature measurements at the furnace exit plane have shown that typical temperatures at full load around the nose area are in excess of 2300 °F. Lower ash fusion temperatures, coupled with higher operational furnace exit temperatures, are probably responsible for the more severe slagging observed at the boiler. A combination of boiler control settings and furnace cleaning schedule was developed and implemented on the boiler for a period of 2 weeks. The field experiments showed very good results with significantly lower ash deposition rates in the most problematic areas of the furnace observed previously.

14/03274 Studies on flow instability of helical tube steam generator with Nyquist criterion

Niu, F. *et al. Nuclear Engineering and Design*, 2014, 266, 63–69.

The steam generator of the 10 MW high-temperature gas-cooled reactor (HTR-10) in China consists of a series of helical tubes where water/steam flows inside and helium flows outside. It operates under middle pressure, which tends to cause the flow instability. Density-wave oscillation is the most common type of two-phase flow instability in the steam generators. This paper presents the research on flow instability for the HTR-10 steam generator. The drift flux model was used for two-phase flow analysis. The transfer matrix was obtained by using linearized perturbation and Laplace transformation on the conservation equations. The flow stability was evaluated by the Nyquist stability criterion. The results obtained from frequency domain method were compared and discussed with the results from the time domain method and the experimental results.

14/03275 Study of combustion process of biodiesel/gasoil mixture in a domestic heating boiler of 26.7 kW

González-González, J. F. *et al. Biomass and Bioenergy*, 2014, 60, 178–188.

This study is focused on the use of biodiesel in a liquid fuel heating boiler of 26.7 kW. The influence of biodiesel/diesel mixtures, air flow rate and input pressure on a combustion process for heating purposes was analysed. The study is divided into two parts. The first deals with the characteristics of biodiesel as a heating fuel and the analysis of its properties and preparation method. The biodiesel was produced from sunflower oil in a pilot plant of 250 L/charge and was characterized according to standard norms. It was found that biodiesel is not acceptable as fuel for internal combustion engines (ester content of 92%). The second part deals with the effect of the operating variables on the combustion parameters in the boiler. The tests were conducted on experimental facilities and the generated emissions were analysed. It was found that increasing the input burner pressure involves a decrease in CO and O_2 and an increase of CO_2 in the fumes, as well as an increase in the combustion process yield. Likewise, a greater air flow rate gives rise to a decrease in the latter parameter. Moreover, CO emissions were slightly higher when biodiesel content was increased in the mixture, and therefore the combustion yield decreased.

14/03276 Study on the characteristics of the supersonic steam injector

Abe, Y. and Shibayama, S. *Nuclear Engineering and Design*, 2014, 268, 191–202.

Steam injector is a passive jet pump which operates without power source or rotating machinery and it has high heat transfer performance due to the direct-contact condensation of supersonic steam flow onto subcooled water jet. It has been considered to be applied to the passive safety system for the next-generation nuclear power plants. The objective of the present study is to clarify operating mechanisms of the steam injector and to determine the operating ranges. In this study, temperature and velocity distribution in the mixing nozzle as well as flow directional pressure distribution were measured. In addition, flow structure in whole of the injector was observed with high-speed video camera. It was confirmed that there were unsteady interfacial behaviour in mixing nozzle which enhanced heat transfer between steam flow and water jet with calculation of heat transfer coefficient. Discharge pressure at diffuser was also estimated with a one-dimensional model proposed previously. Furthermore, it was clarified that steam flow did not condense completely in mixing nozzle and it was two-phase flow in throat and diffuser, which seemed to induce

shock wave. From those results, several discussions and suggestions to develop a physical model which predicts the steam injectors operating characteristics are described in this paper.

14/03277 Ultra-high temperature steam corrosion of complex silicates for nuclear applications: a computational study
Rashkeev, S. N. *et al. Journal of Nuclear Materials*, 2014, 444, (1–3), 56–64.
Stability of materials under extreme conditions is an important issue for safety of nuclear reactors. Presently, silicon carbide (SiC) is being studied as a cladding material candidate for fuel rods in boiling-water and pressurized water-cooled reactors (BWRs and PWRs) that would substitute or modify traditional zircaloy materials. The rate of corrosion of the SiC ceramics in hot vapour environment (up to 2200 °C) simulating emergency conditions of light water reactor (LWR) depends on many environmental factors such as pressure, temperature, viscosity, and surface quality. Using the paralinear oxidation theory developed for ceramics in the combustion reactor environment, the authors estimated the corrosion rate of SiC ceramics under the conditions representing a significant power excursion in a LWR. It was established that a significant time – at least 100 h – is required for a typical SiC braiding to significantly degrade even in the most aggressive vapour environment (with temperatures up to 2200 °C) which is possible in a LWR at emergency condition. This provides evidence in favour of using the SiC coatings/braidings for additional protection of nuclear reactor rods against off-normal material degradation during power excursions or loss-of-coolant accidents. Additionally, the authors discuss possibilities of using other silica based ceramics in order to find materials with even higher corrosion resistance than SiC. In particular, it was found that zircon ($ZrSiO_4$) is also a very promising material for nuclear applications. Thermodynamic and first-principles atomic-scale calculations provide evidence of zircon thermodynamic stability in aggressive environments at least up to 1535 °C.

08 COMBUSTION

Burners, combustion systems

14/03278 A new method for controlling the ignition state of a regenerative combustor using a heat storage device
Marín, P. *et al. Applied Energy*, 2014, 116, 322–332.
Regenerative oxidizers are very useful for combustion of methane–air lean mixtures (<1 vol.% and as low as 0.15%), as those generated in coal mines (ventilation air methane). However, the performance of the oxidizer is unstable, leading to overheating or extinction, when methane concentration varies. The authors propose a new procedure for overcoming this problem, using the heat storage concept. Thus, this issue is addressed by proposing the use of an external sensible heat storage system, added to the regenerative oxidizer, capable of storing the excess of heat released in the oxidizer during rich concentration periods, and using it to heat the feed as needed during lean concentration periods. The performance of the heat storage system has been studied by simulating the behaviour of a regenerative thermal oxidizer designed to operate at 0.25 vol.% nominal feed methane concentration. It was found that the regenerative oxidizer, provided with the heat storage system together with a feedback controller that regulates the heat extracted/introduced in the oxidizers can operate satisfactory, dealing with the variations in methane concentration found in ventilations of coal mines.

14/03279 Advances and challenges in laminar flame experiments and implications for combustion chemistry
Egolfopoulos, F. N. *et al. Progress in Energy and Combustion Science*, 2014, 43, 36–67.
The state of the art and the further challenges of combustion chemistry research in laminar flames are reviewed. Laminar flames constitute an essential part of kinetic model development as the rates of elementary reactions are studied and/or validated in the presence of temperature and species concentration gradients. The various methods considered in this review are the flat, low-pressure, burner-stabilized premixed flame for chemical speciation studies, and the stagnation, spherically expanding, and burner-stabilized flames for determining the global flame properties. The data derived using these methods are considered at present as the most reliable ones for three decades of pressures ranging from about 50 mbar to over 50 bar. Furthermore, the attendant initial and/or boundary conditions and physics are in principle well characterized, allowing for the isolation of various physical parameters that could affect the flame structure and thus the reported data. The merits of each approach and the advances that have been made are outlined and the uncertainties of the reported data are discussed. At the same time, the potential sources of uncertainties associated with the experimental methods and the hypotheses for data extraction using each method are discussed. These uncertainties include unquantified physical effects, inherent instrument limitations, data processing, and data interpretation. Recommendations to reduce experimental uncertainties and increase data fidelity, essential for accurate kinetic model development, are given.

14/03280 Advances in droplet array combustion theory and modeling
Sirignano, W. A. *Progress in Energy and Combustion Science*, 2014, 42, 54–86.
A review of research on the subject of the vaporization and burning of fuel droplets configured in a prescribed array is presented, including both classical works and research over the past decade or two. Droplet arrays and groups and the relation to sprays are discussed. The classical works are reviewed. Recent research on transient burning and vaporization of finite arrays with Stefan convection but without forced convection is presented, including extensions to non-unitary Lewis number and multi-component, liquid fuels. Recent results on transient, convective burning of droplets in arrays are also examined. In particular, transient convective burning of infinite (single-layer periodic and double-layer periodic) and finite droplet arrays are discussed; attention is given to the effects of droplet deceleration due to aerodynamic drag, diameter decrease due to vaporization, internal liquid circulation, and arrays with moving droplets in tandem and staggered configurations. Flame structure is examined as a function of spacing between neighbouring droplets and Damköhler number: individual droplet flames versus group flames and wake flames versus envelope flames. Based on existing knowledge of laminar droplet array and spray combustion theory, experimental evidence, and turbulent studies for non-vaporizing and non-reacting two-phase flows, comments are made on the needs and implications for the study of turbulent spray and array combustion.

14/03281 Analysis of wood firing in stoves by the oxygen consumption method and the carbon dioxide generation method
Paloposki, T. *et al. Biomass and Bioenergy*, 2014, 61, 1–24.
In this paper, the authors describe the application of two experimental methods on the determination of the heat release rate during the combustion of wood in stoves. The experimental methods are the oxygen consumption method and the carbon dioxide generation method and are adopted from the field of fire safety science. After outlining the basic ideas, the authors show the necessary equations and analyse the results from an actual experiment. It was concluded that both methods appear to be very useful in this application.

14/03282 Blending effects on ignition delay times of methyl octanoate/n-nonane/methylcyclohexane
Rotavera, B. and Petersen, E. L. *Fuel*, 2014, 115, 264–281.
Ignition delay times were measured behind reflected shock waves under highly dilute conditions (99% Ar) for 10 ternary blends of methyl octanoate, n-nonane and methylcyclohexane (MCH), using a design-of-experiments approach, namely an L9 array. Measurements were obtained over a wide range of temperatures ($1258 < T(K) < 1630$), pressure ($1.5 < P(atm) < 9.5$), and equivalence ratio ($\varphi = 0.5, 1.0, 2.0$). The series of experiments focused on the effects of variation in relative fuel volume fractions to assess respective influence of hydrocarbon class (i.e. methyl ester, n-alkane, cycloalkane) on ignition delay times of blended fuel. The L9 array utilized for the design of the experimental test matrix led to the development of an empirical ignition delay time correlation which was then employed for a broad series of calculations examining the effects of fuel-ratio variation. Results of the calculations show that addition of methyl octanoate to blends of n-nonane and MCH lowers the power-law pressure dependence of ignition delay times of such blends (the latter two species share similar dependence on pressure). The correlation also shows MCH as the most dominant of the three fuels in the blends studied with respect to controlling ignition delay time, a finding supported by ignition delay time-sensitivity calculations. Calculation of blending effects, defined herein as deviation from neat-fuel behaviour, using the correlation indicated several key features of the studied blends. First, for fixed MCH concentration in a ternary blend, correlation calculations revealed an insensitivity of ignition delay time to variation in the ratio of methyl octanoate to n-nonane for all conditions. Second, blending effects on ignition delay times depend strongly on blend composition and on experimental conditions (pressure, equivalence ratio, temperature), indicating fuel- and condition-specific complexities, although were generally more pronounced at lower temperature. Third, of the three experimental conditions

varied, ignition delay times of fuel blends exhibited the most sensitivity to equivalence ratio. To support experimental results, the study also involved compilation of a detailed chemical kinetics mechanism (4815 reactions, 1082 species) by integrating pertinent reaction chemistry from two independently validated mechanisms into a base model for n-nonane oxidation from a previous study by the authors. Model-based calculations indicate that under stoichiometric conditions near 10 atm, blending effects are negligible above 1350 K yet become increasingly significant towards lower temperature. Lastly, to assess the importance of blending effects, ignition delay times of fuel blends measured experimentally were compared against times calculated using a linear combination method (i.e. superposition of constituent-fuel ignition delay times). In general, superposition of neat-fuel trends cannot be utilized to reproduce ignition trends of the fuel blends here, highlighting the importance of and continued need for blended-fuel studies.

14/03283 Characterization of Hg^0 re-emission and Hg^{2+} leaching potential from flue gas desulfurization (FGD) gypsum

Sun, M. *et al. Fuel Processing Technology*, 2014, 118, 28–33.

A flue gas desulfurization (FGD) system used for SO_2 removal has co-beneficial removal of Hg, which has resulted in Hg-laden gypsums. With growing beneficial reuse applications of the FGD gypsum, it has been recognized as a potential source of Hg pollution. In this paper, the fate and mobility of Hg were investigated. The Hg content in four samples varied widely and it showed a significant correlation between Hg and sulfite contents in gypsum. In leachate, Hg concentration varied during the leaching process. The Hg extraction rate generally increased with decreasing pH value, which suggested that the environmental risk of FGD gypsum increased during the multipurpose utilization processes, resulted from severe acid rain. The released Hg from FGD gypsum used in this study exhibited biphasic kinetics. Hg in FGD gypsum samples not only appeared in the leachate but also re-emitted into the air. The Hg reduction kinetics followed the pseudo-first-order kinetic model well. The results provide the theoretical understanding for the co-removal of highly soluble oxidized Hg in wet flue gas desulfurization systems and also in the recycling of the FGD gypsum.

14/03284 Chemical structure of autoignition in a turbulent lifted H_2/N_2 jet flame issuing into a vitiated coflow

Najafizadeh, S. M. M. *et al. Combustion and Flame*, 2013, 160, (12), 2928–2940.

In the present paper, autoignition is studied as the main stabilization mechanism in turbulent lifted H_2/N_2 jet flames issuing into a vitiated hot coflow. The numerical study is performed using the joint scalar probability denisty function approach with detailed chemistry in a two-dimensional axisymmetric domain. The Speziale, Sarkar and Gatski Reynolds stress model is used as a turbulence model in the simulation. Chemical structure and characteristics of autoignition are investigated using various methods and parameters. Reaction rate analysis is done to analyse the ignition process at the flame base. The results show the occurrence of a chain branching reaction preceding thermal runaway, which boosts the chain branching process in the flame. This demonstrates the large impact of autoignition at the flame base on the stabilization of the lifted turbulent flame. Further investigation using the scatter-plots of scalars reveals the characteristics of the ignition. The relation between the behaviour of temperature and of key intermediate species demonstrates the formation of OH through consumption of HO_2 at nearly isothermal conditions in a very lean-fuel mixture at the flame base. Flux analyses in the conservation equations of species are used to explore the impacts of mass transport on ignition process. Ignition is found to be mainly controlled by chemical features rather than the mixing processes near the flame base. Characteristics of autoignition are also investigated in terms of Damköhler number and progress variable.

14/03285 Co-pyrolysis of heavy oil and low density polyethylene in the presence of supercritical water: the suppression of coke formation

Tan, X.-C. *et al. Fuel Processing Technology*, 2014, 118, 49–54.

At 693 K and water density of 0.30 g/cm^3, the co-pyrolysis of heavy oil and low density polyethylene (LDPE) in the presence of supercritical water (SCW) was investigated with the emphasis on the coking mechanism involved. The co-pyrolysis in SCW was found to have the significant advantages of the decreasing yield of coke and the increasing yield of aromatics over the pyrolysis of heavy oil alone in SCW. With the increase in the loading of LDPE, the suppression of condensation in co-pyrolysis is gradually intensified, suggesting the essential role of LDPE as an external H-source in co-pyrolysis. Only in the continuous SCW phase can the H-donation between the pyrolysis networks of heavy oil and LDPE be effectively accomplished, by which the condensation of light oil fractions to heavy oil fractions and the deep condensation of asphaltenes to coke are partly suppressed.

14/03286 Combustibility of biochar injected into the raceway of a blast furnace

Wijayanta, A. T. *et al. Fuel Processing Technology*, 2014, 117, 53–59.

The combustibility of Taiheiyo coal and oak char in the tuyere and raceway of an iron-making blast furnace was simulated. The effects of injection rate, O_2 concentration and particle diameter on combustibility were studied. Numerical results showed that increasing the O_2 concentration from 23 to 27 wt% resulted in higher combustibility of both solid fuels. However, this effect was insufficient to increase the combustibility of oak char at high injection rates because its volatile content was lower than that of Taiheiyo coal. Temperature and reaction fields were sensitive to both combustion heat and volatile content. A longer raceway or smaller particle size was required to obtain the same combustibility of biochar as of the reference coal. If Taiheiyo coal with a particle diameter of 70 μm was used at a high injection rate of 200 [(kg solid fuel)/(1000 N m^3 feed gas)] with hot blasts containing 27 wt% O_2, the particle diameter of oak char was required to be 60 μm to obtain the same combustibility. These predictions reveal the potential of pulverized biochar injection instead of conventional pulverized coal injection in blast furnace iron-making.

14/03287 Combustion characteristics of biodiesel fuel in high recirculation conditions

Reddy, V. M. *et al. Fuel Processing Technology*, 2014, 118, 310–317.

The potential of biodiesel as an alternative fuel for various applications leads to an investigation to understand the combustion characteristics of pure and blended biodiesel. The concept of internal recirculation of combustion products is employed in a high swirl and low emission burner to reduce emissions. Due to high boiling point (613 K) and Sauter mean diameter (37 μm) of biodiesel, air preheating with minimum temperature above the boiling point of biodiesel is considered. Air at different temperatures of 623, 673 and 703 K is injected tangentially. Swirl flow pattern in the combustor creates the central low pressure zone due to vortex breakdown and improves the recirculation of combustion products. Results in improved mixing and high residence time of reactants. Biodiesel is blended with diesel to reduce the surface tension and viscosity and improve the combustion characteristics. Literature has little consensus on NO_x emissions from the combustion system operating with biodiesel. Therefore, the present study aims to reduce the thermal NO formation through the concept of exhaust gas recirculation. The CO, HC, NO_x emissions and soot-volume fraction from biodiesel (100B0D), 50% blending (50B50D), diesel and kerosene are compared at different air preheating temperatures. A drastic reduction in emissions is observed in 50B50D as compared with pure biodiesel.

14/03288 Combustion of methane/air mixtures in a two-layer porous burner: a comparison of alumina foams, beads, and honeycombs

Gao, H. *et al. Experimental Thermal and Fluid Science*, 2014, 52, 215–220.

This study investigates the premixed combustion of methane/air mixtures in different alumina (Al_2O_3) packings (foams, beads, or honeycombs) based on the almost identical pressure drops for cold flow. A burner was packed with alumina beads with diameter of 3 mm in the preheating zone and 10 ppi (pores per inch) alumina foams, alumina beads with diameter of 13 mm, or 200 cpsi (channels per square inch) alumina honeycombs in the combustion zone. The 10 ppi foams, 13 mm diameter beads or 200 cpsi honeycombs had porosities of 82%, 52% and 80%, respectively. The flame stability limits, flame temperature profiles, flame temperature, pressure drop and pollution emissions for carbon monoxide (CO), hydrocarbon (HC), and nitric oxide (NO_x) for the studied structures are discussed. The flame stability limits are decreased in the order of 10 ppi foams, 13 mm diameter beads and 200 cpsi honeycombs. The flame temperature was significantly affected by heat release at lower flame speed and by heat loss at higher flame velocity under various flame speeds. At the same flame speed, the flame temperature of the foams was significantly lower compared with those of the packed beads and honeycombs because of the significant radiative heat transfer characteristics of the foams. The pressure drop of the reaction flow was significantly higher than that of the corresponding cold flow because of the significant density change. The CO emission was mainly determined by the flame temperature, whereas the HC emission was mainly controlled by the mixing uniformity of fuel/air. The NO_x was very low (< 4 ppm) in the three structures because the flame temperature was relatively low (< 1250 °C).

14/03289 Effect of inlet and outlet configurations on blow-off and flashback with premixed combustion for methane and a high hydrogen content fuel in a generic swirl burner

Syred, N. *et al. Applied Energy*, 2014, 116, 288–296.

The paper analyses new data for three fuels, natural gas, methane and coke oven gas (COG) in two swirl burners. Flashback and blow-off can be correlated with the inlet tangential velocity, not the inlet mass flow, over a range of swirl numbers from 0.8 to more than 4. Geometry and fuel type are important. The correlation gives best fit for a particular outlet geometry and with higher hydrogen content fuels. The correlation still holds with methane and natural gas, especially with confinement. Analysis of the correlation infers that both blow-off and flashback occurrences are governed by the shear layer surrounding the central recirculation zone (CRZ). The CRZ acts to control the width and strength of the shear flow region. Blow-off was found to occur when the CRZ was extensive and well develop and could be modelled by a well-stirred reactor system. Two modes of flashback were found, both of which could be characterized by the same correlation of inlet tangential velocity. The first flashback case occurred at lower swirl numbers when the flame attached to the burner rim and flashed back through the outer boundary layer. At higher swirl numbers the CRZ and associated flame located next to its boundary extended back over the fuel nozzle inside the swirl chamber. Flashback occurred when the flame suddenly moved radially outwards towards the inlets. A clear trend was established for COG; as the swirl number was increased from 0.8 to 1.5 blow-off slightly worsened, whilst flashback improved. Thus higher swirl numbers are tentatively favoured for flashback protection for higher hydrogen content fuels.

14/03290 Evaluation of combustion characteristics in thermogravimetric analyzer and drop tube furnace for Indian coal blends

Sarkar, P. *et al. Applied Thermal Engineering*, 2013, 60, (1–2), 145–151.

The availability of low-ash coals is diminishing in India quickly. As such, trend of utilization of high-ash coals by blending with low-ash coals is increasing rapidly in Indian power plants with the growing demand of coal and with emerging environmental strictures to reduce greenhouse gas emissions and to restrict the ash limit to a targeted value. Quick decisions on the acceptance of certain blends in power stations very often lead to various operational problems and uncertainties. To address such uncertainties in coal combustion, three blend combinations of high-ash–low-ash coals have been examined in this study through laboratory- and bench-scale combustion experiments. Combustion parameters are found to be mostly non-additive. Both synergistic and anti-synergistic combustion characteristics were noticed at different combustion stages. This study reveals necessity of pre-assessment of certain blends through laboratory- and bench-scale studies before those are adopted in power plant. This work also attempts estimation of low-rank intertinite (i.e. reactive component of inertinite having random reflectance $\leq$1.30) followed by 'total reactive content' for prediction of burn out characteristics in thermogravimetric analysis/drop tube furnace. Here, total reactive content is the sum of low-rank inertinite and other traditional reactive macerals, namely, vitrinite, semi-vitrinite and liptinite. Interestingly, satisfactory correlations between 'combustion parameters' and the 'total reactive maceral content' were found.

14/03291 Flame extinction properties of solids obtained from limiting oxygen index tests

Suzanne, M. *et al. Combustion and Flame*, 2014, 161, (1), 288–294.

Extinction theory is used in this work to determine from the limiting oxygen index test (LOI), widely used in industry, flame extinction properties such as the critical mass flux at extinction and its dependence on oxygen concentration. A method for characterizing the chemistry related to extinction, namely activation energy and pre-exponential factor, for an assumed one-step global Arrhenius reaction rate is also presented. In an earlier work, the authors showed how the LOI is related to key flammability properties of a material as measured by thermogravimetric analysis, differential scanning calorimetry, and cone calorimetry. In this study, even though the chemical kinetics for practical materials are unknown, the authors use results from a slightly modified LOI apparatus to derive the material extinction properties, including chemistry effects, by assuming a one-step global Arrhenius reaction rate for extinction. The extinction of flames on a solid surface depends on the flow field through both the heat transferred to the solid and the straining of the flame near stoichiometric conditions. The heat transferred to the solid is determined using a convective heat transfer coefficient, because flame radiation near the surface is small at extinction, and the strain rate affecting the flame reactions is expressed by a characteristic flow time. These flow parameters depend on the local flow conditions. For a counterflow situation, these parameters have been identified in the previous work, whereas for other flow situations, they can be determined from the specific flow field. The ratio of the flow time to the chemical time is used to determine a modified Damköhler number, together with the activation and flame temperatures. The heat transfer coefficient is used to determine the dimensionless mass flux at extinction, which is a function of the Damköhler number.

14/03292 Flame pattern, temperatures and stability limits of pulverized oxy-coal combustion

da Silva, R. C. *et al. Fuel*, 2014, 115, 507–520.

The challenges in maintaining a stable oxy-coal flame have been reported in the open literature. In the case of pulverized coal combustion, narrower flammable regimes arise not only of differences in the feed gas composition, but also due to changes in the flow dynamics because of reduced volume flow rate through the burners to match similar temperatures and radiative heat transfer within the furnace. The present work focuses on the study of flame structure and stability of pre-dried lignite fired by a staged feed-gas burner. Experimental runs were carried out in a 0.40 MW_{th} laboratory facility, with the objective of investigating the effects of swirl strength and feed gas distribution in the burner registers. To assess the experimental data, a numerical study of the non-reacting flow in the near burner region is performed. Predicted flow pattern and flame images show that the primary fuel jet penetrates the internal recirculation zone, forming an annular doughnut reverse flow region for both firing conditions and resembling a type-1 flame pattern. Temperature measurements indicate that the feed gas distribution among the burner registers control the flame temperature in parallel with the swirl number in both air-fired and oxy-fired environments. The oxy-fuel cases exhibit markedly reduced temperatures on the flame axis. This difference in the core arises not just from the more pronounced penetration depth of the primary jet, but also due to reaction mechanisms including pyrolysis and gasification reactions at the higher concentrations of CO_2 and water vapour. Flame stabilization is shown to be strongly dependent on an appropriate distribution of the feed gas and strength of swirling flow in the burner front. The results correlated in terms of swirl number, secondary/tertiary flow ratio and secondary/primary axial momentum point to similarities in the stability limits between air-firing and oxy-firing.

14/03293 Integrated coal pyrolysis with methane aromatization over Mo/HZSM-5 for improving tar yield

Jin, L. *et al. Fuel*, 2013, 114, 187–190.

In this paper, a new process to integrate methane aromatization over Mo/HZSM-5 catalyst with coal pyrolysis was put forward for improving tar yield. Shenmu coal was used to confirm the validity of the process. The effects of pyrolysis temperature, CH_4 flow rate, Mo loading on the tar, water and char yields were investigated in an atmospheric fixed-bed reactor containing upper catalyst layer and lower coal layer. The results show that the tar yield can be improved by integrating the coal pyrolysis with methane aromatization. The tar yield is 21.5 wt% (daf) under the optimum conditions of 700 °C pyrolysis temperature, 25 ml/min CH_4 flow rate, 4 wt% Mo loading and 30 min holding time, obviously higher than 14.6% in N_2 atmosphere and 15.3% in H_2 atmosphere. Further studies confirm the synergistic effect between the coal pyrolysis and methane aromatization.

14/03294 Interaction between iron-based oxygen carrier and four coal ashes during chemical looping combustion

Bao, J. *et al. Applied Energy*, 2014, 115, 549–558.

Chemical looping combustion (CLC) is a novel technology with inherent CO_2 capture, especially for solid fuels. The existence of ash in solid fuels is one major challenge for CLC technology development. In this work, interaction between an iron-based oxygen carrier and four different types of coal ash was studied in a laboratory-scale fluidized reactor. Different factors – the ash component, the redox cycle number, and the ash size – were taken into account. Chemical composition of the ash had effect on the reduction time from Fe_2O_3 to Fe_3O_4 in the fluidized bed. The presence of reactive components (such as Fe_2O_3 and $CaSO_4$) in the ash, functioning as oxygen carriers, extended the reduction time. However, the chemical combination between the ash contents and the carrier can shorten the reduction time. The effect of ash on the carrier's reactivity depended on the ash type. Most ashes decreased the reactivity of the carrier, except the ash mainly composed of $CaSO_4$ which showed an increased reactivity due to the deposited reactive $CaSO_4$. The effect of ash on decreasing the carrier's reactivity increased with the cycles. Meanwhile, the larger ash (900–1000 μm) corresponded to a higher CO conversion, and thus had less effect on the reactivity than the smaller ash (300–400 μm). This occurrence can be attributed to the non-uniform solid–solid contact between the larger ash and the carrier. Sintering and agglomeration of the carrier particles occurred in the existence of most ashes, except the lignite ash enriched in CaO. Ash deposition and the formation of new compounds were detected. One common compound formed in the presence of SiO_2-rich ash was Fe_2SiO_4, which has a low melt point (1170 °C) and a low thermal conductivity with a greater adhesion. The physical ash deposition and the formation of Fe_2SiO_4 through chemical reactions were proposed to be the main reasons for the effect of ash on the carrier's reactivity and the occurrence of sintering and agglomeration. The existence of ash not only has impact on the carrier's reactivity, but also causes solid fluidization disturbances. More effort is deserved to put into the ash-related issue in solid fuel CLC.

14/03295 Laminar burning velocities of primary reference fuels and simple alcohols

Sileghem, L. *et al. Fuel*, 2014, 115, 32–40.

Laminar burning velocities for methanol, ethanol, and binary and quaternary mixtures of these with iso-octane and n-heptane, have been determined using the heat flux method on a flat flame adiabatic burner. Measurements were done for an equivalence ratio range between 0.7 and 1.5 and for a range of temperatures between 298 and 358 K at atmospheric pressure. The present study expands the available data on laminar burning velocities of alcohol–hydrocarbon blends and validates simple mixing rules for predicting the laminar burning velocity for a wider range of fuel blends of hydrocarbons with methanol and/or ethanol. It is shown that simple mixing rules that consider the energy fraction of the blend's components are accurate enough to predict the experimentally determined laminar burning velocity of the mixtures.

14/03296 Large-eddy simulation of spray combustion in a gas turbine combustor

Jones, W. P. *et al. Combustion and Flame*, 2014, 161, (1), 222–239.

The paper describes the results of a comprehensive study of turbulent mixing, fuel spray dispersion and evaporation and combustion in a gas-turbine combustor geometry (the DLR generic single sector combustor) with the aid of large eddy simulation (LES). A Eulerian description of the continuous phase is adopted and is coupled with a Lagrangian formulation of the dispersed phase. The sub-grid scale (*sgs*) probability density function approach in conjunction with the stochastic fields solution method is used to account for *sgs* turbulence–chemistry interactions. Stochastic models are used to represent the influence of *sgs* fluctuations on droplet dispersion and evaporation. Two different test cases are simulated involving reacting and non-reacting conditions. The simulations of the underlying flow field are satisfying in terms of mean statistics and the structure of the flame is captured accurately. Detailed spray simulations are also presented and compared with measurements where the fuel spray model is shown to reproduce the measured Sauter mean diameter and the velocity of the droplets accurately.

14/03297 Measurement on instantaneous flame front structure of turbulent premixed CH_4/H_2/air flames

Zhang, M. *et al. Experimental Thermal and Fluid Science*, 2014, 52, 288–296.

The instantaneous flame front structure of turbulent premixed CH_4/H_2/air flames (hydrogen fraction of 0%, 5%, 10% and 20% by mole fraction) was investigated quantitatively using a nozzle-type Bunsen burner. Hot wire anemometer and OH-PLIF were used to measure the turbulent flow and detect the instantaneous flame front structure, respectively. Turbulent burning velocity, S_T, flame surface density, Σ and mean flame volume, V_f, were calculated by processing the OH-PLIF images. Results show that the flame front structures of the turbulent premixed flames are the wrinkled flame front and it becomes much finer with the increase of turbulence intensity as well as hydrogen fraction. The value of S_T/S_L significantly increases with the increase of u'/S_L and it slightly increases with the increase of hydrogen fraction. Flame surface density profile are symmetric and gives its maximum value at about $\langle c \rangle = 0.5$. Hydrogen addition slightly enhances the Σ and the tendency is more obvious under higher turbulence intensity. The decrease of Σ with the increase of turbulence intensity is mainly due to the effect of flame volume. The mean flame volume of flame region obviously increases with the increase of turbulence intensity within the experimental range due to the increase in depth of the large scale flame wrinkles and flame height. Hydrogen addition is not a predominant factor within the hydrogen fraction range in this study.

14/03298 Measurements of local heat flux to membrane water walls of combustion chambers

Taler, J. *et al. Fuel*, 2014, 115, 70–83.

Three different tubular-type instruments (flux tubes) were developed to identify steady-state boundary conditions in water wall tubes of steam boilers. The first meter is constructed from a short length of eccentric smooth tube containing four thermocouples on the fire side below the inner and outer surfaces of the tube. The fifth thermocouple is located at the rear of the tube on the casing side of the water-wall tube. The second flux tube has two longitudinal fins which are welded to the eccentric smooth tube. In the third solution the fins are attached to the water wall tubes not to the flux tubes as in the second variant of the flux tubes. The first instrument is used to measure the heat flux to water walls made from bare tubes, while another two heat flux tubes are designated for measuring the heat flux to membrane walls. In contrast to the existing devices, the flux-tube is not attached to adjacent water-wall tubes. The boundary conditions on the outer and inner surfaces of the water flux-tube are determined from temperature measurements at interior locations. Temperature dependent thermal conductivity of the flux-tube material was assumed. An inverse problem of heat conduction is solved using the least-squares method. Three unknown parameters are estimated using the Levenberg–Marquardt method. At every iteration step, the temperature distribution over the cross-section of the heat flux meter is determined using ANSYS/CFX software.

14/03299 Oxy-fuel fluidized bed combustion using Victorian brown coal: an experimental investigation

Roy, B. and Bhattacharya, S. *Fuel Processing Technology*, 2014, 117, 23–29.

Oxy-fuel combustion is a promising power generation technology due to its potential for easier CO_2 separation and capture. This when combined with fluidized bed combustion offers additional advantages like fuel flexibility, uniform temperature distribution, low NO_x emissions and in-bed SO_2 capture via sorbent addition. Although few studies have addressed the oxy-fuel fluidized bed combustion of lignites, its applicability using Victorian brown coal has remained unexplored. From experiments in a bench-scale fluidized bed under oxy-fuel combustion condition using Victorian brown coal, this study finds that the flue gas CO_2 concentration increases with oxygen concentration and steam in the feed gas while the effect of temperature is modest between 850 and 900 °C. The addition of steam lowers the trace element retention in ash; this may indirectly affect their partitioning behaviour. These results are important for selection of operating conditions for oxy-fuel fluidized bed combustion of Victorian brown coal.

14/03300 Simultaneous time-resolved fluctuating temperature and acoustic pressure field measurements in a premixed swirl flame

Singh, A. V. *et al. Applied Energy*, 2014, 115, 116–127.

A micro-thermocouple, microphones and microphone probes were employed to provide detailed information on key on-going processes in a premixed swirl flame. High-frequency pressure and temperature measurements were carried out to identify temperature field and acoustic characteristics of a swirl stabilized premixed flame. The local distributions of fluctuating pressure and temperature were measured in different regions, in and around the flame. Noise sources were investigated by using microphone probes and microphone arrays. Temperature and pressure fluctuations were examined both inside and outside the flame boundary. Sensor network used here is essential for the development of advanced combustion systems for it can provide detailed temporal and spatial information that can allow for better control to achieve higher efficiency and performance.

14/03301 Slow pyrolysis of rice straw: analysis of products properties, carbon and energy yields

Park, J. *et al. Bioresource Technology*, 2014, 155, 63–70.

Among many uses of rice straw, application of its biochar from pyrolysis to the soil is receiving greater interest for increased crop productivity and sequestration of CO_2. This study investigated slow pyrolysis of rice straw at 300–700 °C to characterize the yields and detailed composition of the biochar, bio-oil and non-condensable gases. Biochar was analysed for pH, microscopic surface area and pore volume distribution. Although the mass yield for the organic fraction was only about 25% above 500 °C, biochar was the primary product of pyrolysis containing 40% of energy and 45% of carbon from the straw. The utilization of by-products (bio-oil and gases) as energy resources was essential, since the sum of energy yield was about 60%. The gases could be burned to produce the heat for an auto-thermal pyrolysis process, but the heat balance was significantly influenced by the moisture content of the raw material.

14/03302 Study of coal, char and coke fines structures and their proportions in the off-gas blast furnace samples by X-ray diffraction

da S. Machado, A. *et al. Fuel*, 2013, 114, 224–228.

Four dust samples were collected from a blast furnace (BF) for this investigation, two at all-coke and two at pulverized coal injection (PCI) operations. Samples of solid carbonaceous fuels (coals and coke) used in the evaluated BF were utilized. Char samples were produced in the laboratory from the pulverized coals used in PCI. The atomic structure of raw coke, chars and its parent coals used in PCI were investigated. This study utilized the X-ray diffraction technique (XRD) as a standard procedure to identify and differentiate the char and coke structures. This technique was used to quantify the proportions of fines of these carbonaceous materials in the BF flue dust samples. A simplified quantification was proposed. XRD of demineralized dust samples showed the unexpected presence of coke fines in quantities smaller than 63 μm. The quantification of the carbonaceous material present in the BF off-gas samples is important information in order to evaluate the efficiency of the PCI process and the PCI coal combustibility, and it could be used to improve PCI performance in operating blast furnaces.

14/03303 TGA–FTIR investigation of co-combustion characteristics of blends of hydrothermally carbonized oil palm biomass (EFB) and coal

Parshetti, G. K. *et al. Fuel Processing Technology*, 2014, 118, 228–234.
Hydrothermally upgraded chars with improved density and friable characteristics were produced from oil-palm empty fruit bunch (EFB) at three temperatures (150, 250, and 350 °C; denoted as H-150, H-250 and H-350). These chars were co-combusted with low-rank Indonesian coal and with hydrothermally upgraded coal (HT-coal). The composition of major gaseous pollutants released from the co-combustion process with specific reference to CO, CO_2, CH_4, NO and SO_2 was studied in real-time using a thermogravimetric analyser (TGA) coupled with a Fourier transform infrared spectrometry (FTIR). Combustion characteristic factor (*CCF*) was determined for a systematic analysis of the thermal decomposition process. In the co-combustion of hydrothermally treated biomass with coal and HT-coal, H-250 (50%)/HT-coal (50%) ($CCF = 4.1 \times 10^{-7}$) fuel blend showed the highest *CCF* values, i.e. the most efficient co-combustion process. Further analysis of the emission profiles of gaseous pollutants revealed that the co-combustion of 50% H-350 with 50% HT-coal by mass produced the lowest levels of gaseous pollutant emissions. Overall, a systematic combustion carried out in this study showed that co-combustion of hydrothermally upgraded EFB biochar with coal and HT-coal leads to environmental benefits, specifically reduced emissions of toxic (CO), acidic (NO and SO_2) and greenhouse (CH_4 and CO_2) gases.

14/03304 Thermal efficiency of LPG and PNG-fired burners: experimental and numerical studies

Boggavarapu, P. *et al. Fuel*, 2014, 116, 709–715.
In this work, the thermal efficiency of a conventional domestic burner is studied both experimentally and numerically for liquefied petroleum gas (LPG) and piped natural gas (PNG) fuels. Three-dimensional computational fluid dynamic (CFD) modelling of the steady-state flow, combustion and heat transfer to the vessel is reported for the first time in such burners. Based on the insights from the CFD model concerning the flow and heat transfer, design modifications in the form of a circular insert and a radiant sheet are proposed which are observed to increase thermal efficiency for LPG. For PNG, predictions showed that loading height was a much more important factor affecting efficiency than these design modifications and an optimal loading height could be identified. Experiments confirm these trends by showing an improvement in burner thermal efficiency of 2.5% for LPG with the modified design, and 10% for PNG with the optimal loading height, demonstrating that the CFD modelling approach developed in the present work is a useful tool to study domestic burners.

Fire safety

14/03305 A review of chamber experiments for determining specific emission rates and investigating migration pathways of flame retardants

Rauert, C. *et al. Atmospheric Environment*, 2014, 82, 44–45.
The widespread use of flame retardants (FRs) in indoor products has led to their ubiquitous distribution within indoor microenvironments with many studies reporting concentrations in indoor air and dust. Little information is available however on emission of these compounds to air, particularly the measurement of specific emission rates (SERs), or the migration pathways leading to dust contamination. Such knowledge gaps hamper efforts to develop understanding of human exposure. This review summarizes published data on SERs of the following FRs released from treated products: polybrominated diphenyl ethers (PBDEs), hexabromocyclododecanes (HBCDs), tetrabromobisphenol-A (TBBPA), novel brominated flame retardants (NBFRs) and organophosphate flame retardants (PFRs), including a brief discussion of the methods used to derive these SERs. Also reviewed are published studies that utilize emission chambers for investigations/measurements of mass transfer of FRs to dust, discussing the chamber configurations and methods used for these experiments. A brief review of studies investigating correlations between concentrations detected in indoor air/dust and possible sources in the microenvironment is included along with efforts to model contamination of indoor environments. Critical analysis of the literature reveals that the major limitations with utilizing chambers to derive SERs for FRs arise due to the physicochemical properties of FRs. In particular, increased partitioning to chamber surfaces, airborne particles and dust, causes loss through 'sink' effects and results in long times to reach steady state conditions inside the chamber. The limitations of chamber experiments are discussed as well as their potential for filling gaps in knowledge in this area.

14/03306 Effect of blockage-fire distance on buoyancy driven back-layering length and critical velocity in a tunnel: an experimental investigation and global correlations

Tang, W. *et al. Applied Thermal Engineering*, 2013, 60, (1–2), 7–14.
Experiments are conducted in a model tunnel to study the effect of a vehicular blockage at the upstream of the fire source on the buoyancy driven back-layering length and critical velocity in a longitudinal ventilated tunnel. The relative distances between the vehicular blockage and fire source ranged between 1 and 6 m. It is found that with no blockage, experimental data on back-layering length and critical velocity can be well collapsed by the Wu and Li models, respectively. However, with the increase in blockage–fire distance, both the back-layering length and critical velocity first decrease then approach to constants similar to those with no blockage. The modified Wu and Li models amended by cross-sectional blockage ratio proposed by Lee, which does not include the factor of blockage–fire distance, still fail to predict experimental results for different blockage–fire distances. Thus, a dimensionless modification coefficient η is proposed and correlated non-dimensionally with the normalized blockage–fire distance to account for this effect. Finally, global models are proposed to predict back-layering length and critical velocity including factors of both cross-sectional blockage ratio and blockage–fire distance, which are shown to well collapse the experimental measurements in good agreement.

14/03307 Effects of H_2S addition on hydrogen ignition behind reflected shock waves: experiments and modeling

Mathieu, O. *et al. Combustion and Flame*, 2014, 161, (1), 23–36.
Hydrogen sulfide is a common impurity that can greatly change the combustion properties of fuels, even when present in small concentrations. However, the combustion chemistry of H_2S is still poorly understood, and this lack of understanding subsequently leads to difficulties in the design of emission-control and energy-production processes. During this study, ignition delay times were measured behind reflected shock waves for mixtures of 1% H_2/1% O_2 diluted in Ar and doped with various concentration of H_2S (100, 400 and 1600 ppm) over large pressure (around 1.6, 13 and 33 atm) and temperature (1045–1860 K) ranges. Results typically showed a significant increase in the ignition delay time due to the addition of H_2S, in some cases by a factor of 4 or more over the baseline mixtures with no H_2S. The magnitude of the increase is highly dependent on the temperature and pressure. A detailed chemical kinetics model was developed using recent, up-to-date detailed-kinetics mechanisms from the literature and by changing a few reaction rates within their reported error factor. This updated model predicts well the experimental data obtained during this study and from the shock-tube literature. However, flow reactor data from the literature were poorly predicted when H_2S was a reactant. This study highlights the need for a better estimation of several reaction rates to better predict H_2S oxidation chemistry and its effect on fuel combustion. Using the kinetics model for sensitivity analyses, it was determined that the decrease in reactivity in the presence of H_2S is because H_2S initially reacts before the H_2 fuel does, mainly through the reaction $H_2S + H \rightleftharpoons SH + H_2$, thus taking H atoms away from the main branching reaction $H + O_2 \rightleftharpoons OH + O$ and inhibiting the ignition process.

14/03308 Experimental research on the water mist fire suppression performance in an enclosed space by changing the characteristics of nozzles

Liu, Y. *et al. Experimental Thermal and Fluid Science*, 2014, 52, 174–181.
Water mist is an ideal way in enclosed spaces, where fire suppression efficiency is very important due to limited water and water damage to equipment. The purpose of this paper is to find a more effective way of fire suppression performance by changing characteristics of nozzles, taking into account extinguishing time, water consumption, toxic gas concentration, temperature decay and cover area. Two groups of pressure-swirl nozzles with the same flow rate and different spray cone angles were employed. The angle was adjusted by changing diameters and lengths of entrance, swirl chamber and orifice of nozzle. It was found that the cover area and the droplet size increased slightly with the spray angle. The fire tests results showed that the extinguishing time increased with the spray cone angle, and increased with the flow rate and the operating pressure decreasing. The temperature decay rate was improved by decreasing the angle or increasing the flow rate. In addition, with an increase in the extinguishing time, the concentration of O_2 decreased while the CO and CO_2 increased. However, the gas concentrations were not affected by the water mist discharge duration if it exceeded the extinguishing time. For a specific region and a certain amount of water, the performance can be improved by the approach: increasing the flow rate and the spray angle simultaneously and decreasing the discharge duration. The authors suggest setting proper flow rate and spray cone angle which match mutually, in order to maximize the utilization of water.

14/03309 Experimental study on flowing burning behaviors of a pool fire with dripping of melted thermoplastics

Xie, Q. *et al. Journal of Hazardous Materials*, 2014, 267, 48–54.

The objective of this work is to quantitatively investigate the dripping-burning and flowing fire of thermoplastics. A new experimental setup is developed with a heating vessel and a T-trough. Hot thermoplastic liquids are generated in the vessel by electric heating. N_2 gas is continuously injected into the vessel to avoid a sudden ignition of fuel in it. The detailed flowing burning behaviours of pool fire in the T-trough are analysed through the measurements of the mass, heat flux and temperatures etc. The experimental results suggest that a continuous dripping of melted thermoplastic liquids in a nearly constant mass rate can be successfully made in the new setup. It also shows that the mass dripping rate of melted PS liquid is smaller than PP and PE since its large viscosity. In addition, the flame spread velocities of hot liquids of PS in the T-trough are also smaller than that of PP and PE because of its large viscosity. The mass burning rate of the PP and PE pool fire in T-trough are smaller than PS. Finally, considering the heating, melting, dripping and flowing burning behaviours of these polymers, it is suggested that the fire hazard of PE and PP are obviously higher than PS for their faster flowing burning.

14/03310 Linking wildfire effects on soil and water chemistry of the Marão River watershed, Portugal, and biomass changes detected from Landsat imagery

Costa, M. R. *et al. Applied Geochemistry*, 2014, 44, 93–102.

Wildfires transform the landscape, leading to changes in surface cover and, potentially, in water quality. The purpose of this study was to assess changes in the chemical composition of soils and surface water as a result of a wildfire that burned in 2006 in the Marão Mountains, north-eastern Portugal, by comparing pre- and post-fire hydrochemical data and burned/unburned soil data, and to examine the recovery of vegetation over time using Landsat Thematic Mapper (TM) imagery. Studies that have access to pre-fire data are rare and even fewer studies document changes in biomass as a result of fire and during the post-fire recovery period. Samples of ash, soil and water, from within and outside the burned area, were collected 5 months, and 1 year after the fire, for chemical analyses. Landsat TM images were downloaded and transformed into a vegetation index, in order to analyse landcover dynamics and to calculate biomass. The wildfire effects on the Marão River water quality, resulted in an increase in the total mineralization of water. Five months after the wildfire the electrical conductivity (EC) at the mainstem was about 56% higher than pre-fire values (EC increased from 25 to 39 μS/cm) and still higher 1 year after (36 μS/cm). Cations of Ca, Na, Mg and Mn showed the greatest increase. This increase was probably triggered by the movement of ash to the watercourses. This disturbance had already attenuated one year after wildfire to values closer to pre-fire data except for manganese. Manganese had anomalous concentrations in the water within the burned area. The concentration of Mn in ash samples reached values up to five times more than values found in underlying soils. One year after the wildfire, almost all the burned area had recovered with herbaceous vegetation and patches of shrub vegetation. The wildfire burned 1194.7 dry tons of biomass which means, on average, 4.9 dry ton/ha. Based on the mass of burned biomass, approximately 350 g/ha of Mn were released as a result of the fire. It is suggested that this type of calculation can be conducted before a fire to help resource managers understand worst-case scenarios for changes in water quality that have the potential to affect aquatic biotic and the suitability of water for drinking water purposes and agriculture.

14/03311 Markers and influence of open biomass burning on atmospheric particulate size and composition during a major bonfire event

Vassura, I. *et al. Atmospheric Environment*, 2014, 82, 218–225.

This study aims to characterize particulate matter (PM) from the open burning of bonfires as well as detect a series of useful tracer species for source apportionment studies. Total suspended particulate (TSP), PM_{10} and $PM_{2.5}$ were collected before, during, and after St Joseph's Eve (18 March). On this day, several bonfires are lit throughout the study area. Levoglucosan (Lvg), OC, EC, PAHs, soluble ions, and some metals (Al, Cd, Cu, Ni, and Pb) have been determined in each fraction. Results show that the contamination of the area is similar to what is generally found in suburban areas. The fine fraction makes the highest contribution to PM. This fraction is mainly related to compounds composing the PM secondarily formed, while the coarser fractions are associated with natural matrices. The bonfire event is an important source of particulate. All the combustion markers determined in $PM_{2.5}$ [EC, OC, PAHs (except for Flu and Pyr), K^+, Cl^-, and Lvg] register a higher concentration. Lvg/OC ratio confirms higher wood smoke emissions during these days. Both the concentration and the compound profile indicate a different origin of PAHs in the atmosphere. The highest concentration of K^+ and OC in TSP confirm the contribution of open fire, as well, to this fraction, which can be ascribable mainly to combustion ash. Nitrates and sulfates also show a higher concentration in the PM_{10}-TSP fraction. Surprisingly, there is also an increase in the concentration of components not usually considered combustion markers, i.e. Pb and Al in $PM_{2.5}$. This is probably ascribable to their bioaccumulation. In conclusion, Lvg, OC, PAHs, Al, and Pb can be used together as specific markers of bonfires to identify this source of particulate matter.

14/03312 Pool fires – an empirical correlation

Ditch, B. D. *et al. Combustion and Flame*, 2013, 160, (12), 2964–2974.

This study presents the experimental procedure and results of highly controlled pool fire tests, in a quiescent environment, designed to accurately measure the fuel burning rate and, consequently for sufficiently large pools, the thermal radiation flux back to the fuel surface. Steps were taken to minimize the effects of in-depth absorption of flame radiation, circulation within the liquid, and changes in fuel composition due to distillation of more volatile fuel components. With these precautions, focus is placed on gas phase phenomena controlling the heat release rate per unit pool area. The primary variables considered are: pool diameter, heat of gasification, flame sootiness as characterized by the inverse of the fuel smoke-point flame height, and, to a lesser extent, absorption of flame radiation by the fuel vapours just above the liquid surface. Results reported in this paper agree well with literature values for experiments conducted under similarly controlled conditions. A simple empirical formula is developed based primarily on heat of gasification and smoke point and is shown to correlate the mass burning rate within 9%, on average, of the experimental data.

14/03313 Smoke suppression properties of ferrite yellow on flame retardant thermoplastic polyurethane based on ammonium polyphosphate

Chen, X. *et al. Journal of Hazardous Materials*, 2014, 266, 114–121.

This paper studies smoke suppression properties and synergistic flame retardant effect of ferrite yellow (FeOOH) on flame retardant thermoplastic polyurethane (TPU) composites using ammonium polyphosphate (APP) as a flame retardant agent. Smoke suppression properties and synergistic flame retardant effect of FeOOH on flame retardant TPU composites were intensively investigated by smoke density test (SDT), cone calorimeter test (CCT), scanning electron microscopy (SEM), and thermogravimetric analysis (TGA). Remarkably, the SDT results show that FeOOH can effectively decrease the amount of smoke production with or without flame. On the other hand, the CCT data reveal that the addition of FeOOH can apparently reduce heat release rate, total heat release and total smoke release, etc. Here, FeOOH is considered to be an effective smoke suppression agent and a good synergism with APP in flame retardant TPU composites, which can greatly improve the structure of char residue realized by TGA and SEM results.

14/03314 Ventilation effects in confined and mechanically ventilated fires

Lassus, J. *et al. International Journal of Thermal Sciences*, 2014, 75, 87–94.

The main objective of this work is to study under-ventilated and highly under-ventilated fires in a compartment equipped with a mechanical ventilation network. Heptane and dodecane pool fire experiments are performed in a reduced-scale room. A changing-scale analysis is performed in order to obtain species concentrations and temperature levels at a larger scale. Carbon dioxide concentration increases linearly with the decreasing of oxygen concentration. Heat release rate depends on ventilation condition in the compartment and three cases can be distinguished. The first one corresponds to sufficiently ventilated fires, where heat release rate is higher or equal to the one of an open fire and where the reaction is almost complete. The second one includes under-ventilated fires for oxygen concentration ranging between the minimum oxygen concentration of the given fuel and around 7% (this value corresponds to the minimum oxygen concentration of carbon monoxide). At this percentage of oxygen, the heat release rate is lower than the one of an open fire and the carbon monoxide production is proportional to oxygen concentration. The third one corresponds to very under-ventilated fires for oxygen concentration lower than 7%, and where the fire can stop due to a lack of oxygen. In this case, carbon monoxide concentration increases strongly with the decrease of oxygen concentration.

09 PROCESS HEATING, POWER AND INCINERATION

Energy applications in industry

14/03315 A sparse heteroscedastic model for the probabilistic load forecasting in energy-intensive enterprises

Kou, P. and Gao, F. *International Journal of Electrical Power & Energy Systems*, 2014, 55, 144–154.

Energy-intensive enterprises (EIEs) account for a significant part of the total electricity consumption in most industrial countries. In the smart grid environment, electric load forecasting in EIEs plays a critical role in the security and economical operation of both the main grid and the EIEs' micro-grid. However, the accuracy of such forecasting is highly variable due to the strong stochastic nature of the load in EIEs. In this circumstance, probabilistic forecasts are essential for quantifying the uncertainties associated with the load, thus is highly meaningful for assessing the risk of relying on the forecasts and optimizing the energy systems within EIEs. This paper focuses on the day-ahead probabilistic load forecasting in EIEs, a novel sparse heteroscedastic forecasting model based on Gaussian process is developed. With the proposed model, predictive distributions can be provided that capture the heteroscedasticity of the load in EIEs. Since the high computational complexity of Gaussian process hinder its practical application to large-scale problems such as load forecast, the proposed model employs the $\ell_{1/2}$ regularizer to reduce its computational complexity, thereby enhancing its practical applicability. The simulation on real world data validates the effectiveness of the proposed model. The data used in the simulation are obtained in the real operation of an EIE in China.

14/03316 A stable synergistic microbial consortium for simultaneous azo dye removal and bioelectricity generation

Wang, V. B. *et al. Bioresource Technology*, 2014, 155, 71–76.

Microbial species coexist in natural or engineered settings, where they encounter extensive competition and cooperation. Interactions occurring through metabolite exchange or direct contact might be important in establishment of functional biodegradation consortium. Understanding these interactions can facilitate manipulation of selected communities and exploitation of their capacity for specific industrial applications. Here, a simple dual-species consortium (*Pseudomonas putida* and *Shewanella oneidensis*) was established for examining simultaneous Congo red bioremediation in planktonic culture and power generation in anode biofilms. Compared to mono-species cultures, co-cultures generated higher current densities and could concurrently degrade Congo red over 72 h. Disabling the large secreted adhesion protein, LapA, of *P. putida* greatly enhanced *S. oneidensis* biofilm formation on the anode, which increased power generation in co-cultures. This demonstrates simultaneous control of specific planktonic and biofilm communities could be effective in manipulating microbial communities for targeted applications.

14/03317 Alternate approximation of concave cost functions for process design and supply chain optimization problems

Cafaro, D. C. and Grossmann, I. E. *Computers & Chemical Engineering*, 2014, 60, 376–380.

This paper presents an alternate approximation of concave cost functions used to reflect economies of scale in process design and supply chain optimization problems. To approximate the original concave function, the authors propose a logarithmic function that is exact and has bounded gradients at zero values in contrast to other approximation schemes. The application and advantages of the proposed approximation are illustrated.

14/03318 Computational methods for the simultaneous strategic planning of supply chains and batch chemical manufacturing sites

Corsano, G. *et al. Computers & Chemical Engineering*, 2014, 60, 154–171.

This work presents efficient solution strategies for the task of designing supply chains with the explicit consideration of the detailed plant performance of the embedded facilities. Taking as a basis a mixed-integer linear programming (MILP) model introduced in a previous work, the authors propose three solution strategies that exploit the underlying mathematical structure: a bi-level algorithm, a Lagrangian decomposition method, and a hybrid approach that combines features from both of these two methods. Numerical results show that the bi-level method outperforms the others, leading to significant computer processing savings when compared to the full space MILP.

14/03319 Heat recovery opportunities in UK industry

Hammond, G. P. and Norman, J. B. *Applied Energy*, 2014, 116, 387–397.

A database of the heat demand, and surplus heat available, at UK industrial sites involved in the European Union Emissions Trading System, was used to estimate the technical potential of various heat recovery technologies. The options considered were recovery for use on-site, using heat exchangers; upgrading the heat to a higher temperature, using heat pumps; conversion of the heat energy to fulfil a chilling demand, using absorption chillers; conversion of the heat energy to electrical energy, using Rankine cycles; and transport of the heat to fulfil an off-site heat demand. A broad analysis of this type, which investigates a large number of sites, cannot accurately identify site level opportunities. However the analysis can provide an indicative assessment of the overall potential for different technologies. The greatest potential for reusing this surplus heat was found to be recovery at low temperatures, utilizing heat exchangers; and in conversion to electricity, mostly using organic Rankine cycle technology. Both these technologies exist in commercial applications, but are not well established, support for their development and installation could increase their use. The overall surplus heat that was technically recoverable using a combination of these technologies was estimated at 52 PJ/year, saving 2.2 $MtCO_{2e}$/year in comparison to supplying the energy outputs in a conventional manner. It is thought that a network and market for trading in heat and the wider use of district heating systems could open considerable potential for exporting heat from industrial sites to other users.

14/03320 Identifying torsional modal parameters of large turbine generators based on the supplementary-excitation-signal-injection test

Xie, X. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 56, 1–8.

Torsional parameters, especially modal frequencies and mechanical damping, of large turbine generators play critical roles in evaluating and solving the subsynchronous resonance or oscillation problem. To accurately identify these torsional parameters, this paper proposes a systematic approach based on the supplementary-excitation-signal-injection test. The identification process is fulfilled via three steps, i.e. (1) accurate detection of modal frequencies by stimulating controllable torsional vibration with the injection of supplementary modal signals into the excitation system; (2) online identification of total modal damping using modal filtration, improved discrete Fourier transform and least-square fitting technique; (3) separating electrical damping from the identified modal damping to get the pure mechanical modal damping. The proposed approach was verified through digital simulation and then was applied to the torsional-parameter identification of four practical turbine-generators in Shangdu power plant. The results demonstrated that, with the proposed approach, the modal frequencies and mechanical damping can be obtained accurately, intact and without interfering with the normal operation of on-grid generators.

14/03321 Impact of CaO and $CaCO_3$ addition on agglomeration/defluidization and heavy metal emission during waste combustion in fluidized-bed

Liu, Z.-S. *et al. Fuel Processing Technology*, 2014, 118, 171–179.

In this study, CaO and $CaCO_3$ were used as additives to investigate the inhibition of agglomeration/defluidization and adsorption of Pb and Cd. The results showed that defluidization time may be prolonged when CaO or $CaCO_3$ is added to the artificial waste. Before defluidization, Pb and Cd emissions were not intensified significantly in the existence of Na; however, after defluidization, the emission of Pb and Cd increased significantly. The heavy metal emission concentration was lower when CaO or $CaCO_3$ was added to the artificial waste than when only Na was added. $CaCO_3$ showed a stronger defluidization inhibition effect because of the longer defluidization time. For different parameters, the heavy metal emission concentration appeared to decrease with an increase in the operating temperature; however a change in the gas velocity did not affect the heavy metal emission. In addition, an increase in the bed material size considerably reduces the defluidization time. A small bed material size is more favoured as the large specific surface area in this case allows for the adsorption of a greater amount of heavy metal and more efficient mixing with waste.

14/03322 Indirect thermal integration for batch processes

Chaturvedi, N. D. and Bandyopadhyay, S. *Applied Thermal Engineering*, 2014, 62, (1), 229–238.

Rigorous algorithms to target the minimum utility requirements for single as well as cyclic batch processes are proposed in this paper. Practically, heat integration between two different time intervals requires indirect integration through intermediate fluid. Targets, calculated via proposed methodology, account for indirect thermal integration in batch process. The proposed methodology overcomes limitations of existing methodologies and guarantees the optimality as it is proved to be optimum using rigorous mathematical arguments. This methodology is applicable to any fixed-scheduled batch process. Applicability of the proposed methodology is demonstrated through illustrative examples. In one of the illustrative examples, a reduction of 18.7% and 16.4% (in comparison to time slice model) is observed in hot and cold utility requirements, respectively.

14/03323 Influence of cryogenic cooling on surface grinding of stainless steel 316
Manimaran, G. *et al. Cryogenics*, 2014, 59, 76–83.
The objective of the present investigation is to evaluate the improvements in the grinding force and surface roughness by the application of LN_2 (liquid nitrogen) as a coolant in the cryogenic grinding process. Cryogenic machining is an environment concerned green manufacturing process. The grinding experiments were conducted on stainless steel 316 in three environments, namely, dry, wet and cryogenic cooling. The experimental results show that a reduction in the grinding zone temperature leads to excellent benefits in the machining performance. The cryogenic coolant offers 37% and 13% reduction in the grinding forces compared to dry and wet cooling. The surface roughness under cryogenic cooling is found to produce 59% and 32% lesser values and fewer defects, compared to surfaces ground with dry and wet cooling. The enhancements realized by the delivery pressure of the cryogen, with respect to the grinding forces, and surface roughness were also studied.

14/03324 Integration of biogas plants in the building materials industry
Ellersdorfer, M. and Weiß, C. *Renewable Energy*, 2014, 61, 125–131.
This paper quantifies the synergy-effects of an areal combination of biogas-plants with plants of the building materials industry (e.g. cement works) from the energetic and economic point of view. Therefore, an overall process model based on energy and mass flow balances is developed to determine the effects of a combination of both plants in terms of energetic efficiency, investment and operating costs, greenhouse gas emissions reduction and overall energy production costs. The results and the calculation procedure for a combination of biogas plants with cement works are presented in detail. The main benefits of this combination are the utilization of low temperature excess heat sources from cement works for fermenter heating and the direct thermal utilization of unprocessed biogas as a valuable, CO_2-neutral fuel for combustion processes, for instance clinker burning. Due to the combination, the energetic efficiency of the biogas plant, defined as utilizable energy output in relation to the energy content of the produced biogas, significantly increases from 63.0% to 83.8%. Concurrently, the energy production costs are reduced, turning biogas into a competitive source of energy without the need for federal sponsorship. Calculations show, that production costs in combined plants for plant sizes larger than 90 m^3_{STP}/h biogas are even lower than the actual market price of natural gas.

14/03325 New candle prototype for hot gas filtration industrial applications
Alonso-Fariñas, B. *et al. Fuel*, 2013, 114, 120–127.
The improvement of gas cleaning technologies is crucial for the establishment of advanced clean power generation coal-based technologies such as integrated gasification combined cycle (IGCC) or pressurized fluidized bed combustion (PFBC) which need a high performance of the syngas clean-up process. New materials and advanced operating strategies at higher temperatures that could give lower energy penalty are required to be developed. A large-scale high-temperature filtration pilot plant is available at the ETSI University of Seville in Spain. This pilot plant allows for the testing of different filtering elements and pulse cleaning strategies using real coal ash under an extensive range of operating temperature and pressure conditions. The aim of this research is the evaluation of the alternatives for hot gas filtration technologies and the optimization of the operation and performance of the filtering elements. An experimental campaign was carried out to test a new type of silicon carbide candle. Some prototype candles were fabricated from pyrolysed wood and other materials as result of a novel environmentally friendly patented process (BioSiC®). This process provides good thermomechanical, chemical and structural stability in an extensive range of temperatures. The main parameters for the characterization of the prototype were studied such as filtration velocity, permeability, porosity, pressure drop across the filter, cleaning pulse interval, baseline pressure drop, filtration efficiency and durability of the filter. Optimal operating conditions and pulse cleaning strategies were determined. Additionally, a model to predict the behaviour of the filtering elements under diverse operating conditions was developed. In general, the experimental results showed that the prototypes are suitable for industrial applications under the operating conditions typical of those required for hot gas cleaning of coal combustion and gasification gases, as used in this study. However, the possible improvements in the performance of the elements were identified that should be carried out in the next experimental campaign. This paper describes the main characteristics of the new material developed as well as the major results and conclusions from the analysis.

14/03326 The effect of long lead times for planning of energy efficiency and biorefinery technologies at a pulp mill
Svensson, E. and Berntsson, T. *Renewable Energy*, 2014, 61, 12–16.
The pulp and paper industry has many promising opportunities in the biorefinery field. To reach this potential, investments are required in new, emerging technologies and systems solutions which cannot be implemented quickly. In this paper, an approach to model the necessarily long planning times for this kind of investments is presented. The methodology used is based on stochastic programming, and all investments are optimized under uncertain energy market conditions. The uncertain cost development of the emerging technologies is also considered. It is analysed using scenario analysis where both the cost levels and the timing for market introduction are considered. The effect of long lead times is studied by assuming that no investments can be decided on now and implemented already today, and only investments planned for today can be implemented in, for example, 5 years. An example is presented to illustrate the usefulness of the proposed approach. The example includes the possibility of future investment in lignin separation, and shows how the investment planning of industrial energy efficiency investments can be guided by using the proposed systematic approach. The example also illustrates the value of keeping flexibility in the investment planning.

14/03327 Thermoeconomic and ecological analysis applied to heating industrial process in chemical reactors
de Souza, S. A. and de Queiroz Lamas, W. *Renewable and Sustainable Energy Reviews*, 2014, 29, 96–107.
This work presents a case that evaluates the possible environmental and economic gains of the application of water solar heating as an alternative for the consumption of natural gas in chemical reactors for cosmetic industries. The proposal consists of pre-heating of water for a boiler to produce steam to heat several reactors from an industrial unit and measure the impacts caused by this application. An analysis methodology is used based on the thermoeconomic optimization of a steam generation unit and production reactors heating in a chemical plant. This methodology at first identifies the system functions as a whole and then individually for each unit, creating the thermoeconomic functional diagram, formulating the cost problem and solving the mathematical equations associated to the system. Based on the investment demands, expected results for fossil fuel consumption reduction and a consequently beneficial impact on the amount of greenhouse gases emissions and a payback of approximately 2 years, this solution might be considered attractive.

10 SPACE HEATING AND COOLING/HEAT PUMPS

14/03328 A compact thermal heat switch for cryogenic space applications operating near 100 K
Dietrich, M. *et al. Cryogenics*, 2014, 59, 70–75.
A thermal heat switch has been developed intended for cryogenic space applications operating around 100 K. The switch was designed to separate two pulse tube cold heads that cool a common focal plane array. Two cold heads are used for redundancy reasons, while the switch is used to reduce the thermal heat loss of the stand-by cold head, thus limiting the required input power, weight and dimensions of the cooler assembly. After initial evaluation of possible switching technologies, a construction based on the difference in the linear thermal expansion coefficients (CTE) of different materials was chosen. A simple design is proposed based on thermoplastics which have one of the highest CTE known permitting a relative large gap width in the open state. Furthermore, the switch requires no power either during normal operation or for switching. This enhances reliability and allows for a simple mechanical design. After a single switch was successfully built, a second double-switch configuration was designed and tested. The long term performance of the chosen thermoplastic (ultra-high molecular weight polyethylene) under cryogenic load is also analysed.

14/03329 A modified two-stage pulse tube cryocooler utilizing double-inlet and multi-mesh regenerator

Arablu, M. and Jafarian, A. *Cryogenics*, 2013, 58, 26–32.

In this paper, a thermally coupled Stirling-type two-stage pulse tube cryocoolers (TSPTC) is studied using a one-dimensional computational fluid dynamics code. After validating the results of the simulations, effects of synchronous utilization of multi-mesh regenerator and double-inlet on the performance of the TSPTC are investigated. Results of simulations show that non-oscillating friction factors do not possess sufficient accuracy for calculation of oscillating friction losses in non-porous media. Whereas, using oscillating friction factor of non-porous media leads to sufficient accurate results. According to the results, using multi-mesh regenerator and double-inlet increases the coefficient of performance and decreases the minimum attainable temperature of the system. It is observed that a minimum temperature of 18.2 K is attainable using optimum multi-mesh regenerator and double-inlet; whereas, for a simple TSPTC with a uniform mesh regenerator, a minimum temperature of 26.4 K is concluded.

14/03330 A new approach to optimize thermoelectric cooling modules

Jeong, E. S. *Cryogenics*, 2014, 59, 38–43.

A theoretical investigation to optimize thermoelectric cooling modules is performed using a novel one-dimensional analytic model. In the model, the optimum current, which maximizes the coefficient of performance (COP) of a thermoelectric cooling module, is determined by the cooling capacity of a thermoelement, the hot and cold side temperatures, the thermal and electrical contact resistances and the properties of thermoelectric material, but not by the length of a thermoelement. The optimum length of a thermoelement can be easily obtained using the optimum current. The effects of the thermal and electrical contact resistances, the cooling capacity of a thermoelement and the cold side temperature on the maximum COP, the optimum electric current and the optimum thermoelement length are shown.

14/03331 A new method to estimate heat source parameters in gas metal arc welding simulation process

Jia, X. *et al. Fusion Engineering and Design*, 2014, 89, (1), 40–48.

Heat source parameters were usually recommended by experience in welding simulation process, which induced error in simulation results (e.g. temperature distribution and residual stress). In this paper, a new method was developed to accurately estimate heat source parameters in welding simulation. In order to reduce the simulation complexity, a sensitivity analysis of heat source parameters was carried out. The relationships between heat source parameters and welding pool characteristics [fusion width (W), penetration depth (D) and peak temperature (T_p)] were obtained with both the multiple regression analysis (MRA) and the partial least-squares regression analysis (PLSRA). Different regression models were employed in each regression method. Comparisons of both methods were performed. A welding experiment was carried out to verify the method. The results showed that both the MRA and the PLSRA were feasible and accurate for prediction of heat source parameters in welding simulation. However, the PLSRA was recommended for its advantages of requiring less simulation data.

14/03332 A novel sebacic acid/expanded graphite composite phase change material for solar thermal medium-temperature applications

Wang, S. *et al. Solar Energy*, 2014, 99, 283–290.

This paper demonstrates a novel sebacic acid/expanded graphite (SA/EG) composite phase change material (PCM) for medium-temperature solar heat storage. The optimal mass percentage of SA in the SA/EG composite PCM is determined to be around 85%, at which not only SA exhibits a uniform distribution into the pores of EG but also the liquid leakage can be effectively prevented. The composite PCM with the SA mass percentage of 85% has a phase change temperature of 128 °C with the latent heat as high as *ca*. 187 J/g. The combination of SA and EG effectively prevents the low extent of subcooling inherent in SA. Compared to SA, the SA/EG composite PCM has the advantages of negligible subcooling as well as better thermal reliability and stability. The SA/EG composite PCM can easily be formed into various shapes by dry pressing, with little loss in thermal properties but a remarkable increase in thermal conductivity. The good thermal properties and formability make the SA/EG composite PCM show great potential in latent heat storage systems.

14/03333 A review of forced convection heat transfer enhancement and hydrodynamic characteristics of a nanofluid

Hussein, A. M. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 734–743.

The low thermal properties of liquids have led to investigations into additives of small size (<100 nm solid particles) to enhance their heat transfer properties and hydrodynamic flow. To summarize the experimental and numerical studies, this paper reviews these computational simulations and finds that most of them are in agreement with the results of experimental work. Many of the studies report enhancements in the heat transfer coefficient with an increase in the concentration of solid particles. Certain studies with a smaller particle size indicated an increase in the heat transfer enhancement when compared to values obtained with a larger size. Additionally, the effect of the shape of the flow area on the heat transfer enhancement has been explored by a number of studies. All of the studies showed a nominal increase in pressure drop. The significant applications in the engineering field explain why so many investigators have studied heat transfer with augmentation by a nanofluid in the heat exchanger. This paper presents a review of the heat transfer applications of nanofluids to develop directions for future work. The high volume fraction of various nanofluids will be useful in car radiators to enhance the heat transfer numerically and experimentally. Correlation equations can expose relationships between the Nusselt number, the Reynolds number, the concentration and the diameter of the nanoparticles. On the other hand, more work is needed to compare the shapes (e.g. circular, elliptical and flat tube) that might enhance the heat transfer with a minimal pressure drop.

14/03334 A stand-alone solar adsorption refrigerator for humanitarian aid

Santori, G. *et al. Solar Energy*, 2014, 100, 172–178.

Solar adsorption ice makers are devices which could prove a great help in sustaining the cold chain in developing countries. The use of such devices could be extended also in supporting humanitarian aid actions for vaccine storage, for example. However, further development and optimization of the system design are still required. In this paper a new, versatile, solar-driven ice maker operating with the activated carbon/methanol adsorption pair has been developed and tested. The field tests carried out on February and March 2013, showed that the prototype is able to produce up to 5 kg of ice, with a solar coefficient of performance of about 0.08, and to preserve it for whole next day. The overall dimensions of the realized prototype are $1.7 \times 1.5 \times 0.95$ m. Solar radiation is collected by a solar collector with an exposed area of 1.2 m^2.

14/03335 A study on the use of phase change materials (PCMs) in combination with a natural cold source for space cooling in telecommunications base stations (TBSs) in China

Sun, X. *et al. Applied Energy*, 2014, 117, 95–103.

A technology that combines phase change materials (PCMs) with a natural cold source is proposed to reduce the space cooling energy of telecommunications base stations (TBSs). First, a mathematical model was developed to assess this technology. Then, a full-scale prototype, named latent heat storage unit (LHSU), was designed, built, and tested in an enthalpy difference laboratory. The energy efficiency ratio (EER) and the adjusted energy efficiency ratio (AEER) were used as the criteria to evaluate the performance of this unit and to compare it with conventional air conditioners. LHSU performance simulations were carried out based on the unit's operation in TBSs located in five Chinese cities with different climates. The simulated average annual AEER was 14.04 W/W, which is considerably higher than the limiting value of 3.2 W/W for air conditioners with a cooling capacity of less than 4500 W. The estimated average energy savings potential of the LHSU was 50%. Based on these results, it was concluded that LHSUs could be used in TBSs to reduce a significant amount of their energy consumed in space cooling.

14/03336 An evaluation of heat transfer and effectiveness for unglazed transpired solar air heaters

Collins, M. R. and Abulkhair, H. *Solar Energy*, 2014, 99, 231–245.

The use of unglazed transpired solar collectors (UTSCs) is considered to be one of the most effective methods of reducing heating, ventilation and air-conditioning system (HVAC) loads in buildings. The operation of the UTSC is relatively simple. A perforated absorber plate is installed in a location where it is exposed to solar radiation. Air is drawn through the perforations, and into the fresh air intake of an HVAC system. This pre-warmed air could make a significant contribution towards decreasing the energy used for heating. Unfortunately, commercially available UTSC products are no longer geometrically similar to the products used to produce correlations used by designers for estimating heat loss and effectiveness. The intent of the current investigation, therefore, is to numerically investigate modern UTSC system performance. Numerical development was successful, and the model was validated by comparison to existing experiments and correlations. An experimental investigation, however, is still required to provide formal validation. Correlations for heat loss and effectiveness have been developed.

14/03337 Bipolar porous polymeric frameworks for low-cost, high-power, long-life all-organic energy storage devices

Sakaushi, K. *et al. Journal of Power Sources*, 2014, 245, 553–556.

Organic-based energy storage devices are of great interest due to their potential as affordable, high-performance energy storage devices. Especially, all-organic energy storage devices, where cathode and anode are constituted of organic compounds, could be an extremely affordable device expected to be applied to smart grids. Recent reports on bipolar porous polymeric frameworks (BPPFs) suggest very promising features of this new organic electrode group towards high-performance energy storage devices. Here, the authors studied an all-organic system using BPPFs for both anode and cathode parts. The formation of BPPFs was confirmed by Raman spectroscopy and N_2 isotherm measurements. The electrochemical properties of this all-organic energy storage device using BPPFs showed a high-power density of $1\,kW\,kg^{-1}$ based on the total mass of the BPPFs and a long cycle life of over 1000 times.

14/03338 Combining the demand response of direct electric space heating and partial thermal storage using LP optimization

Ali, M. *et al. Electric Power Systems Research*, 2014, 106, 160–167.

This study optimized the demand response (DR) control of partial storage electric space heating using a linear programming (LP) approach. The objective was to combine the DR control of direct electric space heating and partial thermal storage in order to minimize the total energy cost of customers without sacrificing user comfort. The proposed DR control was optimized according to the dynamic prices, which shifts the power demand from peak price periods to the cheapest hours. The optimal load shaping strategy was examined by performing simulations. The simulation results show that the partial heat storage together with thermal inertia of the house can offer much flexibility in DR control. The optimal DR control model can easily be integrated at the household level for better utilization of distributed energy resources under the smart grid scenario.

14/03339 Conceptual design of passive containment cooling system with air holdup tanks in the concrete containment of improved APR+

Jeon, B. G. and No, H. C. *Nuclear Engineering and Design*, 2014, 267, 180–188.

The accident of the Fukushima nuclear power plant in Japan emphasized passive systems against prolonged station blackout. This paper considers conceptual design of passive containment cooling system (PCCS) based on APR+, an advanced pressurized water reactor developed in Korea with passive auxiliary feedwater system (PAFS). In the design, decay heat removal rate is to be maximized by introducing air holdup tanks (AHT). The AHT is an isolated space disposed above IRWST and is connected to the containment free space by vent lines through IRWST water and PAFS heat exchangers (HXs), where steam generated by decay heat is condensed. Since a lot of steam is condensed through in-tube HXs and IRWST water, air is mainly transported into the AHT decreasing air mass fraction near HXs inside containment and increasing heat transfer rates. Several design options (AHT volume, flow distribution in vent lines, HX types) are evaluated via scoping analysis. The scoping analysis had proved that AHT (>10% containment volume) decreased the required number of PCCS HXs to be installed less than a half, failure of valves caused marginal increase in HXs to be installed, and external HXs had merits over in-tube HXs for long-term cooling.

14/03340 Energy analysis of thermal energy storages with grid configurations

Rezaie, B. *et al. Applied Energy*, 2014, 117, 54–61.

In some thermal networks, such as district energy systems, conditions can exist, depending on space availability, economics, project requirements, insulation, storing media type and other issues, for which it may be advantageous to utilize several thermal energy storages (TESs) instead of one. Here, various configurations for multiple TESs are proposed and investigated. Significant parameters for a TES, or a set of TESs, include discharging temperature and recovered energy. First, one TES is modelled to determine the final temperature, energy recovery, and energy efficiency. Next, characteristics for various grid configurations of multiple TESs are developed as functions of TES characteristics (e.g. charging and discharging temperatures and energy quantities). Series, parallel and comprehensive grid TES configurations are considered. In the parallel configuration, the TESs behave independently. This suggests that the TES can consist of different storage media types and sizes, and that there is no restriction on initial temperature of the TES. In the series configuration, the situation is different because the TESs are connected directly or indirectly through a heat exchanger. If there is no heat exchanger between the TESs, the TES storage media should be the same, because the outlet of one TES in the series is the inlet to the next. The initial temperature of the second TES must be smaller than the discharge temperature of the first. There is no restriction on the TES size for series configurations. The general grid configuration is observed to exhibit characteristics of both series and parallel configurations.

14/03341 Enhanced heat dissipation of a radiator using oxide nano-coolant

Nieh, H.-M. *et al. International Journal of Thermal Sciences*, 2014, 77, 252–261.

This study adopts an alumina (Al_2O_3) and titania (TiO_2) nano-coolant (NC) to enhance the heat dissipation performance of an air-cooled radiator. The two-step synthesis method is used to produce different concentrations of Al_2O_3 and TiO_2/water (W) nanofluid by using a 0.2 wt% chitosan dispersant, and the nanofluid is mixed with ethylene glycol (EG) at a 1 : 1 volume ratio to form NC_1 to NC_6. The experiments were conducted to measure the thermal conductivity, viscosity, and specific heat of the NC with different concentrations of nanoparticles and sample temperatures, and then the NC was used in an air-cooled radiator to evaluate its heat dissipation capacity, pressure drop, and pumping power under different volumetric flow rates and heating temperatures. Finally, this study evaluates the relationship of the heat dissipation capacity and pumping power by using the efficiency factor (EF). The experimental results show that the heat dissipation capacity and the EF of the NC are higher than EG/W, and that the TiO_2 NC is higher than the Al_2O_3 NC according to most of the experimental data. The maximum enhanced ratios of the heat dissipation capacity, pressure drop, pumping power, and EF for all the experimental parameters are approximately 25.6%, 6.1%, 2.5% and 27.2%, respectively, compared with EG/W. Overall, the NC improves the heat dissipation capacity and EF of the cooling system; however, the enhanced ratio of the pressure drop and pumping power is not obvious in this study.

14/03342 Evaluation of thermal short-circuiting and influence on thermal response test for borehole heat exchanger

Li, Y. *et al. Geothermics*, 2014, 50, 136–147.

Fluid extracts or rejects heat with subsurface by downward leg of pipe (DLP) and upward leg of pipe (ULP) inside the vertical borehole heat exchanger (BHE). As the borehole diameter is only 0.11–0.20 m, the temperature difference between DLP and ULP inevitably leads to thermal short-circuiting. In order to discuss how different geometrical characteristics influence on short-circuiting, the heat transfer between the two legs was investigated by a two-dimensional model, and then a best-fit expression of short-circuiting thermal resistance was presented in dimensionless form. A three-dimensional equivalent rectangular numerical model was established to evaluate the fluid temperature variations along the pipe, how the flow velocity and grout conductivity and borehole depth influence on the outlet temperature and average heat flux per unit length and short-circuiting loss rate were analysed. By comparing the arithmetic average fluid temperature and integral average fluid temperature, it was found that the lager short-circuiting loss rate would lead to greater error for effective subsurface conductivity estimation. The experiment done in NanJing, China also validated that the smaller flow velocity and larger borehole depth would bring about the smaller measured effective subsurface conductivity during a thermal response test.

14/03343 Experimental and computational evolution of a shell and tube heat exchanger as a PCM thermal storage system

Hosseini, M. J. *et al. International Communications in Heat and Mass Transfer*, 2014, 50, 128–136.

A combined experimental and numerical study has been designed to study thermal behaviour and heat transfer characteristics of paraffin RT50 as a phase change material (PCM) during constrained melting and solidification processes inside a shell-and-tube heat exchanger. A series of experiments are conducted to investigate the effects of increasing the inlet temperature of the heat transfer fluid (HTF) on the charging and discharging processes of the PCM. The computations are based on an iterative, finite-volume numerical procedure that incorporates a single-domain enthalpy formulation for simulation of the phase change phenomenon. The molten front at various times of process has been studied through a numerical simulation. The experimental results show that by increasing the inlet HTF temperature from $T_H = 70\,^{\circ}C$ to 75 and 80 °C, theoretical efficiency in charging and discharging processes rises from 81.1% to 88.4% and from 79.7% to 81.4%, respectively.

14/03344 Experimental investigation of a novel asymmetric heat spreader with nanostructure surfaces

Sun, Z. *et al. Experimental Thermal and Fluid Science*, 2014, 52, 197–204.

A novel asymmetric vapour chamber is developed in this study. In this vapour chamber, nanostructure is patterned on the inner top surface of condensing wall and this condensing wall is made to be super-hydrophobic to replace the conventional porous wick. This improvement not only results in drop-wise condensation which has a much higher heat transfer coefficient compared with film condensation, but also provides a shortcut for the condensed water to drop back directly to the centre wick. Thus, a smaller liquid flow resistance and higher anti-dryout capability are achieved. The evaporator wick is made of sintered multi-layer copper powder. The dimensions of the vapour chamber are $70 \times 70 \times 3\,mm^3$. The test module includes an aluminium block with recirculated cooling water going through it and a heater with an area of $1.5 \times 1.5\,cm^2$. The optimum working pressure is determined by testing the performance of the vapour chamber under different initial pressures. Heater temperature, horizontal resistance and vertical resistance are identified as key parameters to evaluate the performance of heat spreader. It is found that heater temperature increases with increasing heat flux. However, the vertical resistance shows the opposite tendency with increasing heat flux. The performance of the novel vapour chamber is compared with that of a conventional vapour chamber and copper plate. The newly developed vapour chamber can greatly reduce the heater temperature. Furthermore, better temperature uniformity and a lower vertical resistance can be achieved for the newly developed vapour chamber which is promising for the thermal management of high power electronic devices.

14/03345 Experimental investigation of heat transfer coefficient and friction factor of ethylene glycol water based TiO_2 nanofluid in double pipe heat exchanger with and without helical coil inserts

Reddy, M. C. S. and Rao, V. V. *International Communications in Heat and Mass Transfer*, 2014, 50, 68–76.

Heat transfer coefficient and friction factor of TiO_2 nanofluid flowing in a double pipe heat exchanger with and without helical coil inserts are studied experimentally. The experiments are conducted in the range of Reynolds number from 4000 to 15,000 and in the volume concentration range from 0.0004% to 0.02%. The base fluid is prepared by considering 40% of ethylene glycol and 60% of distilled water. The heat transfer coefficient and friction factor get enhanced by 10.73% and 8.73% for 0.02% volume concentration of nanofluid when compared to base fluid flowing in a tube. Heat transfer coefficient and friction factor further get enhanced by 13.85% and 10.69% respectively for 0.02% nanofluid when compared to base fluid flowing in a tube with helical coil insert of $P/d = 2.5$. The measured values of heat transfer coefficient and friction factor are compared with the published literature. Based on the experimental data, generalized correlations are proposed for Nusselt number and friction factor. The results are presented in graphical and tabular form. Uncertainty analysis is also carried out and the experimental error is in the range of $\pm 10\%$.

14/03346 Experimental investigation on the heat transfer performance and water condensation phenomenon of radiant cooling panels

Yin, Y. L. *et al. Building and Environment*, 2014, 71, 15–23.

Radiant cooling system is a promising technique which is suitable for independent control processes of temperature and humidity. The two main benefits of radiant cooling systems include the potential to save energy and improvement of indoor thermal comfort. However, both the poor heat transfer performance and condensation below dew point temperature restrict the widespread utilization in the residential buildings especially in humid environment. This research was focused on comprehending detailed performance of the radiant cooling panel when it used as an air-conditioning system. Three radiant cooling panels with the area of $0.16\,m^2$ were prepared for investigation and a constant temperature and humidity environment chamber employed to simulate the different indoor thermal environments. The heat transfer performance and moisture condensation phenomenon of the radiant cooling panels were investigated. The results showed that the flow state of chilled water had the biggest influence on the heat transfer performance of the radiant cooling panels. The temperature difference between chilled water and the ambient was also observed to significantly affect the performance. Condensation of moisture on the radiant cooling panels was noted to increase the heat transfer quantity, but posed a challenge in using of the radiant cooling panel. Taking the performance of heat transfer and moisture condensation into consideration, the gypsum radiant cooling panel showed the best performance as compared to the metal radiant cooling panel and pure tube panel. The radiant cooling panels can work more efficiently especially when proper control strategies are employed to avoid condensation.

14/03347 Experimental research on thermal characteristics of a hybrid thermocline heat storage system

Yin, H. *et al. Applied Thermal Engineering*, 2014, 62, (1), 293–301.

Considering the high-temperature thermal utilization of solar energy as the research background in this paper and focussing on the heat storage process, a kind of hybrid thermocline heat storage method in multi-scale structure and relevant experimental systems are designed by using the mixed molten nitrate salt as the heat storage medium and two representative porous materials, i.e. zirconium ball and silicon carbide (SiC) foam, as the heat storage fillers. The fluid flow and heat storage performance of molten salt in multi-scale structure are experimentally investigated. The results show that the theoretical heat storage efficiencies amongst the three experimental heat storage manners are less than 80% because of the existence of thermocline layers. Comparing to the single-phase molten salt heat storage, the two hybrid thermocline heat storage manners with porous fillers lead to a certain decrease in the effective heat storage capacity. The presence of porous fillers can also help to maintain the molten salt fluid as ideal gravity flow or piston flow and partially replace expensive molten salt. Therefore, it requires a combination of heat storage capacity and economical consideration for optimization design when similar spherical particles or foam ceramics are employed as the porous fillers.

14/03348 Experimental study of moisture uptake of polyurethane foam subjected to a heat sink below 30 K

Zhang, X. B. *et al. Cryogenics*, 2014, 59, 1–6.

Rigid closed-cell foam is widely used to thermally insulate liquid hydrogen and oxygen tanks of space launch vehicles due to its lightweight, mechanical strength and thermal-insulating performance. Up to now, little information is available on the intrusion of moisture into the foam that subjects one side to liquid hydrogen temperatures and the other side to room temperatures and high relative humidity. A novel cryogenic moisture uptake apparatus has been designed and fabricated to measure the moisture uptake into the polyurethane foam. For safety and convenience, two identical single-stage pulse tube cryocoolers instead of liquid hydrogen are used to cool one side of the foam specimen to the lowest temperature of 26 K. A total of eight specimens in three groups, according to whether there is a butt-joint or weathering period, are tested respectively for both 5 and 9 h. The additional weight due to moisture uptake of the foam for the 26 K cases is compared to previous measurements at 79 K. The results are instructive for the applications of foam to the insulation of liquid hydrogen tanks in space launch vehicles.

14/03349 Experimental study on defrosting mechanism of intermittent ultrasonic resonance for a finned-tube evaporator

Tan, H. *et al. Experimental Thermal and Fluid Science*, 2014, 52, 308–317.

This paper proposes a new defrosting method based on ultrasonic resonance mechanism to solve the problem of the unknown mechanism of ultrasonic defrosting for a finned-tube evaporator. Dynamic microscopic process of frost crystals formation and growth under the natural frost condition was first investigated. According to the growth characteristics of the frost crystals, the natural frequencies of frost crystals with different height were calculated in COMSOL software. An ultrasonic transducer of 28 kHz/60 W was adopted as an executor to excite the evaporator, then ultrasonic defrosting experiments and laser vibrometer experiments were carried out under the excitation of the ultrasonic transducer. Finally, experiment of ultrasonic resonance based on intermittent operational was studied to optimize ultrasonic loading method. It was found that the height of the frost crystals were about 0.5 mm after growing for 4 min, the average natural frequency of the frost crystals were about 27.95 kHz, the evaporator and frost crystals on the fin surface were forced vibration at the frequency of 28.2 kHz, which was the actual working frequency of the ultrasonic transducer detected in laser vibrometer experiment, and most frost crystals with certain shape and size were immediately broken up when the ultrasonic vibration applied. The main mechanism of ultrasonic defrosting was the resonance effect of natural frequency of frost crystals and excitation frequency, and the optimal working mode of ultrasonic resonance defrosting was intermittent 4 min, vibration 1 min. The experiment's results also showed that ultrasonic shear stress and acceleration effect of ultrasonic also had defrosting performance, but they were not the main mechanism for ultrasonic defrosting.

14/03350 Experimental study on the convective heat transfer enhancement in single-phase steam flow by a support grid

Kim, B. J. *et al. Annals of Nuclear Energy*, 2014, 63, 409–416.

Single-phase flow occurs in the fuel rod bundle of a pressurized water reactor during the normal operation period or at the early stage of the reflood phase in a loss-of-coolant accident scenario. In the former period, the flow is single-phase water flow, but in the latter case, the flow is single-phase steam flow. Support grids are required to maintain a proper geometry configuration of fuel rods within nuclear fuel assemblies. This study was conducted to elucidate the effects of support grids on the convective heat transfer in single-phase steam flow.

Experiments were made in a square array 2×2 rod bundle. The four electrically heated rods were maintained by support grids with mixing vanes creating a swirl flow. Two types of support grids were considered in this study. The two types are geometrically similar except the blockage ratio by different mixing vane angles. For all test runs, 2 kW power was supplied to each rod. The working fluid was superheated steam with $Re = 2301–39{,}594$. The axial profile of the rod surface temperatures was measured, and the convective heat transfer enhancement by the presence of the support grids was examined. The peak heat transfer enhancement was a function of not only the blockage ratio but also the Reynolds number. Given the same blockage ratio, the heat transfer enhancement was sensitive to the Reynolds number in laminar flow, whereas it was nearly independent of the Reynolds number in turbulent flow.

14/03351 Experimentally validated two dimensional numerical model for the solidification of PCM along a horizontal long tube

Ismail, K. A. R. *et al. International Journal of Thermal Sciences*, 2014, 75, 184–193.

This paper presents the results of a numerical study validated by experimental measurements on the solidification of phase change materials (PCM) along a horizontal tube by using the boundary immobilization technique. The two-dimensional model (r,z) of the phase change problem is formulated based on the energy equation and the Landau transform which transforms the moving irregular interfaces to fixed parallel interfaces. The finite volume method is used to discretize the system of equations and the associated boundary and initial conditions. A computer program was elaborated and the time and space grids were optimized to make the numerical solution insensitive to the grid size. The model was validated against experimental and numerical results available in the literature and good agreement was found. Additional results were obtained and the numerical predictions were found to agree well with the new measurements showing that the immobilization technique is adequate to handle phase change problems.

14/03352 Fatty acids as phase change materials: a review

Yuan, Y. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 482–498.

Fatty acids used as phase change materials (PCMs) have attracted much attention for their various applications in building energy efficiency, solar heating systems and air-conditioning systems. After summarizing the basic characteristics of fatty acids, eutectic mixtures of fatty acids and fatty acid esters, as well as the preparation and characteristics of fatty acid composites as PCMs, this paper analyses the thermal reliability and stability of fatty acids as PCMs and their heat transfer characteristics in a unit which is followed by an introduction to the energy storage systems of three kinds of fatty acids as PCMs. It also points out the future research direction of fatty acids as PCMs as a solution of the insufficiency and flaws of current research.

14/03353 Flow boiling heat transfer coefficients at cryogenic temperatures for multi-component refrigerant mixtures of nitrogen–hydrocarbons

Ardhapurkar, P. M. *et al. Cryogenics*, 2014, 59, 84–92.

The recuperative heat exchanger governs the overall performance of the mixed refrigerant Joule–Thomson cryocooler. In these heat exchangers, the non-azeotropic refrigerant mixture of nitrogen–hydrocarbons undergoes boiling and condensation simultaneously at cryogenic temperature. Hence, the design of such heat exchanger is crucial. However, due to lack of empirical correlations to predict two-phase heat transfer coefficients of multi-component mixtures at low temperature, the design of such heat exchanger is difficult. The present study aims to assess the existing methods for prediction of flow boiling heat transfer coefficients. Many correlations are evaluated against available experimental data of flow boiling of refrigerant mixtures. Silver–Bell–Ghaly correlation and Granryd correlation are found to be more suitable to estimate local heat transfer coefficients. A modified Granryd correlation is recommended for further use.

14/03354 From heat exchanger to heat adaptor: concept, analysis and application

Zhang, Y. *et al. Applied Energy*, 2014, 115, 272–279.

Based on the analogy between electricity and heat, electric transformers and heat exchangers were found to have many similarities. However, unlike transformers where V_o can be higher than V_i, the outlet temperatures of conventional heat exchangers are limited (i.e. $T_{c,o} < T_{h,i}$, $T_{h,o} > T_{c,i}$). Therefore, the effectiveness of a heat exchanger cannot exceed unity. Such limitations make it difficult to identify and evaluate thermal equipment or systems for many applications. For example, in city central heating systems, in order to reduce the flow rate of the heat transfer fluid in the primary heat network, m (energy consumption for transporting the fluid is proportional to m^3), $T_{h,o}$ is often expected to be lower than $T_{c,i}$. In this case a traditional heat exchanger cannot meet this requirement. How to conveniently identify or evaluate the most suitable system for such applications is an important but unsolved problem. This study proposes a new concept, the heat adaptor, to address this problem. The idea is to combine heat-work conversion equipment (heat engines and/or heat pumps) with conventional heat exchangers. Using this concept, a typical process of a heat adaptor is established and its thermal performance is analysed. The results show that the best process and best device arrangement can be obtained for given conditions, and that the thermal performance of these processes can be evaluated.

14/03355 High precision in-cylinder gas thermometry using laser induced gratings: quantitative measurement of evaporative cooling with gasoline/alcohol blends in a GDI optical engine

Williams, B. *et al. Combustion and Flame*, 2014, 161, (1), 270–279.

The first application of laser-induced thermal gratings spectroscopy (LITGS) for precision thermometry in a firing gasoline direct injection (GDI) optical engine is reported. Crank-angle resolved temperature values were derived from LITGS signals generated in fuel vapour with a pressure-dependent precision in the range 0.1–1.0% allowing differences in evaporative or charge cooling effects arising from a variety of ethanol and methanol blends with a model gasoline fuel to be quantified. In addition, fluctuations in temperature arising from cyclic variations in compression were directly detected and measured.

14/03356 Hydrodynamic parameters for ErPr cryocooler regenerator fillers under steady and periodic flow conditions

Pathak, M. G. *et al. Cryogenics*, 2013, 58, 68–77.

The regenerator, typically a microporous structure that is subject to periodic flow of a cryogenic fluid, is the most critical component of pulse tube or Stirling cryocoolers, which are widely used for high-demand defence and aerospace applications. Despite the critical impact of hydrodynamic irreversibilities in the regenerator on the overall cycle efficiency, the impact of the parameters that influence these losses are poorly understood. In this investigation, experiments were conducted in which steady and oscillatory flows of helium were imposed on $Er_{50}Pr_{50}$ rare-earth regenerator filler material and mass flow and pressure drop data were recorded under ambient temperature conditions. A filler material composed of 63–75 μm diameter $Er_{50}Pr_{50}$ spheres was selected based on current commercially available particle geometries. The flow parameters in the experiments were in the laminar flow range. A computational fluid dynamic-assisted method was applied for the analysis and interpretation of the experimental data, with sinusoidal time variations of inlet and exit boundary conditions for the periodic flow case. The permeability and inertial coefficients that led to agreement between the experimental data and computational simulations were iteratively obtained. The resulting Darcy permeability and Forchheimer inertial coefficients are reported herein. A constant Darcy permeability value for all steady and periodic flow tests was found to correlate well to experimental data. The Forchheimer inertial coefficients were correlated and found to be functions of the system charge pressure and the pore-based Reynolds number. The results also show that the periodic flow inertial coefficients are different than the steady flow parameters typically used.

14/03357 Lattice Boltzmann simulation of natural convection heat transfer in an open enclosure filled with Cu–water nanofluid in a presence of magnetic field

Hussein, A. K. *et al. Nuclear Engineering and Design*, 2014, 268, 10–17.

In this paper, magnetohydrodynamic natural convection flow of Cu–water nanofluid in an open enclosure is investigated numerically using lattice Boltzmann method scheme. The effective thermal conductivity and viscosity of nanofluid are calculated by the Maxwell–Garnetts and Brinkman models, respectively. In addition, the multi-distribution-function model was used for simulating the effect of uniform magnetic field. The influence of pertinent parameters such as Hartmann number, nanoparticle volume fraction, Rayleigh number and the inclination of magnetic field on the flow and heat transfer characteristics have been examined. The results indicate that the absolute values of stream function decline significantly by increasing Hartmann numbers while these values rise by increasing Rayleigh numbers. Moreover, the results show that the solid volume fraction has a significant influence on stream function and heat transfer, depending on the value of Hartmann and Rayleigh numbers.

14/03358 Low cryogen inventory, forced flow Ne cooling system with room temperature compression stage and heat recuperation

Shornikov, A. *et al. Cryogenics*, 2014, 59, 7–11.

This study presents design and commissioning results of a forced flow cooling system utilizing neon at 30 K. The cryogen is pumped through the system by a room-temperature compression stage. To decouple the

cold zone from the compression stage a recuperating counterflow tube-in-tube heat exchanger is used. Commissioning demonstrated successful condensation of neon and transfer of up to 30 W cooling power to the load at 30 K using only 30 g of the cryogen circulating in the system at pressures below 170 kPa.

14/03359 Microstructural modeling of thermal conductivity of high burn-up mixed oxide fuel

Teague, M. *et al. Journal of Nuclear Materials*, 2014, 444, (1–3), 161–169.

Predicting the thermal conductivity of oxide fuels as a function of burn-up and temperature is fundamental to the efficient and safe operation of nuclear reactors. However, modelling the thermal conductivity of fuel is greatly complicated by the radially inhomogeneous nature of irradiated fuel in both composition and microstructure. In this work, radially and temperature-dependent models for effective thermal conductivity were developed utilizing optical micrographs of high burn-up mixed oxide fuel. The micrographs were employed to create finite element meshes with the OOF2 software. The meshes were then used to calculate the effective thermal conductivity of the microstructures using the BISON fuel performance code. The new thermal conductivity models were used to calculate thermal profiles at end of life for the fuel pellets. These results were compared to thermal conductivity models from the literature, and comparison between the new finite element-based thermal conductivity model and the Duriez–Lucuta model was favourable.

14/03360 Modeling a channel-type reactor with a plate heat exchanger for cobalt-based Fischer–Tropsch synthesis

Shin, M.-S. *et al. Fuel Processing Technology*, 2014, 118, 235–243.

A channel-type reactor for the cobalt-based Fischer–Tropsch synthesis reaction was considered and a commercial software package (COMSOL Multiphysics) was used to simulate the profiles of conversion and temperature in the reactor under a variety of conditions. The CO consumption rate was calculated using a lumped kinetic model, and kinetic parameters and the heat transfer coefficient between the reaction module and the atmosphere were estimated to reduce deviations from the experimental measurements. Comparison between simulation results and experimental data corroborated the validity of the developed model with errors lower than 7.00% and 0.15% for CO conversion and temperature in the catalytic bed, respectively. Further examination showed that the increased heat transfer rate in the channel-type reactor resulted in nearly isothermal operation in the catalytic bed, and the temperature was satisfactorily controlled even when the modules were numbered-up for high capacity. In addition, the effect of coolant flow-rate was evaluated to determine operating conditions in the case of numbering-up of reaction modules.

14/03361 Modeling phase change materials behavior in building applications: comments on material characterization and model validation

Dutil, Y. *et al. Renewable Energy*, 2014, 61, 132–135.

In a recent International Energy Agency meeting, several members presented their conclusions on the modelling of the behaviour of phase change materials (PCM) in the context of building applications. These conclusions were in agreement with those of a vast review, involving the survey of more than 250 journal papers, undertaken earlier by the group of École de technologie supérieure. In brief, it can be stated that, at this point, the confidence in reviewed models is too low to use them to predict the future behaviour of a building with confidence. Moreover, it was found that overall thermal behaviours of PCM are poorly known, which by itself creates an intrinsic unknown in any model. Models themselves are most of time suspicious as they are often not tested in a very stringent or exhaustive way. In addition, it also appears that modelling parameters are somewhat too simplified to realistically describe the complete physics needed to predict the real-life performance of PCMs added to a building. As a result, steps are now taken to create standard model benchmarks that will improve the confidence of the users. Hopefully, following these efforts, confidence will increase and usage of PCM in buildings should be eased.

14/03362 New test methodologies to analyse direct expansion solar assisted heat pumps for domestic hot water

Facão, J. and Carvalho, M. J. *Solar Energy*, 2014, 100, 66–75.

Since there are not specific standards for testing direct expansion solar-assisted heat pumps for domestic hot water, new testing methodologies are proposed supported by laboratory experiments. Two methodologies were developed for performance measurement: modified BIN method and long-term performance prediction with a TRNSYS model validated with specific experimental conditions. The long-term performance prediction is a methodology similar to the already obtained for solar thermal systems. A system was tested in Lisbon during a year, covering almost all possible local weather conditions. The hot water tapping test cycle used was in agreement with recent standards EN16147:2011 or EN15316–3–1:2007. The influence of average daily air temperature, dew point temperature and solar irradiation was analysed. The seasonal performance factor was calculated for two cities in Portugal (Lisbon and Porto) and for additional four cities in Europe (Davos, Athens, Helsinki and Strasburg). The establishment of a procedure to calculate the seasonal performance of this kind of systems is very important according to the directive 2009/28/EC of the European Parliament and of the Council.

14/03363 Numerical study on the thermal behavior of phase change materials (PCMs) embedded in porous metal matrix

Li, Z. and Wu, Z.-G. *Solar Energy*, 2014, 99, 172–184.

This study investigated numerically the thermal behaviour of a phase change material (PCM), sodium nitrate ($NaNO_3$), inside a porous metal matrix for thermal energy storage (TES) applications. The copper matrix with high thermal conductivity, a large surface area and good mechanical properties, is used as metal skeletons. The effects of heat conduction through metal matrix structures, natural convection of liquid PCM, and the detailed parameters such as porosity and pore density of metal matrix were numerically examined for the TES systems in both melting and solidification processes. The results firstly show the heat transfer coefficient of the TES with copper matrix can be significantly increased up to 28.1 times by heat conduction when PCM is in solid phase, and up to 3.1 times by the combination of natural convection and heat conduction when PCM is in liquid phase. Hence, both the melting and solidification times are substantially shortened: in the melting process, the minimum melting time for $NaNO_3$ embedded with 90% porosity and 10 ppi is 20% of that with pure $NaNO_3$; in the solidification process, the minimum solidification time for $NaNO_3$ embedded with 90% porosity and 30 ppi is only 3.9% of that with pure $NaNO_3$. By using numerical method, the authors could easily sort out a composite with optimized physical parameters to guarantee both the heating and cooling rates are high. This numerical method could improve the understanding of flow and heat transfer mechanisms in porous material, and these prospective results are anticipated to be valuable for optimizing the porosity and pore density to make the most effective energy transport in practical applications.

14/03364 Optimization of the working fluid for a sorption-based Joule–Thomson cooler

Wu, Y. *et al. Cryogenics*, 2013, 58, 5–13.

Sorption-based Joule–Thomson coolers operate free of vibration, have a potentially long life time and cause no electromagnetic interference. Therefore, they are appealing to a wide variety of applications, such as cooling of low-noise amplifiers, superconducting electronics and optical detectors. The required cooling temperature depends on the device to be cooled and extends into the cryogenic range well below 80 K. This paper presents a generalized methodology for optimization in a sorption-based Joule–Thomson cooler. The analysis is based on the inherent properties of the fluids and the adsorbent. By using this method, the working fluid of a Joule–Thomson cooler driven by a single-stage sorption compressor is optimized for two ranges of cold-tip operating temperatures: 65–160 K and 16–38 K. The optimization method is also extended to two-stage compression and specifically nitrogen and carbon monoxide are considered.

14/03365 Optimum design of a radial heat sink with a fin-height profile for high-power LED lighting applications

Jang, D. *et al. Applied Energy*, 2014, 116, 260–268.

Light-emitting diode (LED) lighting offers greater energy efficiency than conventional lighting. However, if the heat from the LEDs is not properly dissipated, the lifespan and luminous efficiency are diminished. In the present study, a heat sink of LED lighting was optimized with respect to its fin-height profile to obtain reliable cooling performance for high-power LED lighting applications. Natural convection and radiation heat transfer were taken into consideration and an experiment was conducted to validate the numerical model. Fin-height profiles reflecting a three-dimensional chimney-flow pattern were proposed. The outermost fin height, the difference between fin heights, and the number of fin arrays were adopted as design variables via sensitivity analysis, and the heat sink configuration was optimized in three dimensions. Optimization was conducted to simultaneously minimize the thermal resistance and mass. The result was compared with the Pareto fronts of a plate-fin heat sink examined in a previous study. The cooling performance of the optimized design showed an improvement of more than 45% while preserving a mass similar to that of the plate-fin heat sink.

14/03366 Phase change material: optimizing the thermal properties and thermal conductivity of myristic acid/palmitic acid eutectic mixture with acid-based surfactants

Fauzi, H. *et al. Applied Thermal Engineering*, 2013, 60, (1–2), 261–265.

In this study, the addition of a surfactant to fatty acids as phase change materials (PCMs) for solar thermal applications is proposed. The incorporation of surfactant additives into a eutectic mixture of fatty acids can significantly increase the value of latent heat storage and can

suppress undercooling. The authors report the preparation of myristic acid/palmitic acid (MA/PA) eutectic mixture as PCM with addition of 0, 5, 10, 15, and 20% sodium myristate (SM), sodium palmitate (SP) and sodium stearate (SS), the influence of surfactant additives on thermal properties and thermal conductivity of eutectic mixtures. It was found that the addition of 5% SM, 5% SP and 5% SS to MA/PA eutectic mixture is very effective in depressing the liquid/solid phase change temperature, reducing the undercooling and increasing the amount of latent heat of fusion as well as thermal conductivity of eutectic PCM compared to eutectic PCM without surfactants. Furthermore MA/PA + 5%SS has the highest latent heat of fusion of 191.85 J g^{-1}, while MA/PA + 5%SM showed the least undercooling of 0.34 °C and the highest thermal conductivity of 0.242 W m^{-1} K^{-1}.

14/03367 Photon transport effect on intra-subassembly thermal power distribution in fast reactor

Chiba, G. *et al. Annals of Nuclear Energy*, 2014, 65, 41–46.

In order to accurately predict intra-subassembly thermal power distribution in a fast reactor, neutron and photon transport calculations are carried out with a multi-purpose reactor physics calculation code system CBZ. All the fission fragment nuclide are treated explicitly during fuel depletion, and irradiation time-dependent energy spectra of delayed fission γ-rays emitted from all the fission fragment nuclides are precisely simulated. Time-dependent delayed β-ray emission and transmutations of fission fragment nuclide by neutron-nuclide reactions are also taken into account. A fuel subassembly model of Japanese prototype fast reactor Monju is used for numerical calculations, and their two-dimensional geometric feature is precisely modelled by a ray-tracing-based collision probability method implemented in CBZ. When the photon transport is considered, total thermal powers in fissile material regions are reduced by about 1.5% except at the beginning of fuel depletion.

14/03368 Predicting the thermal conductivity and temperature distribution in 3D braided composites

Jiang, L.-l. *et al. Composite Structures*, 2014, 108, 578–583.

This paper presents a modified finite element model to investigate the thermal conductivity and temperature distribution of three-dimensional (3D) braided composites. The effective coefficients of thermal conductivity (CTC) of the 3D braided composites are predicted. The effects of the braiding angle and fibre volume fraction on the effective CTC are evaluated. The results are compared with the experimental data available in the literature to demonstrate the accuracy and reliability of the present method. The temperature distributions of the representative volume element are also outlined under different temperature boundary conditions, which provide a basis for the analysis of the coupling problem of thermomechanics.

14/03369 Preparation, thermal and rheological properties of hybrid nanocomposite phase change material for thermal energy storage

Parameshwaran, R. *et al. Applied Energy*, 2014, 115, 320–330.

This paper presents the experimental investigation on the thermal properties and viscosity of the new organic ester phase change material (PCM) embedded with the silver–titania hybrid nanocomposite (HyNPCM) with the mass proportions ranging from 0.1% to 1.5%. The HyNPCM embedded with the surface functionalized hybrid nanocomposite exhibited improved thermal conductivity from 0.286 to 0.538 W/m K, congruent phase change temperature (6.8 °C), high latent heat capacity (90.81 kJ/kg), substantial reduction in the supercooling degree (1.82 °C), thermal stability (191 °C) and chemical stability, while compared to the pure PCM. Experimental results reveal that the freezing and the melting times of the HyNPCM were reduced by 23.9% and 8.5%, respectively, when compared to the pure PCM. The increased mass proportion of HyNC resulted in the increased viscosity up to 3.89%, which suggests the existence of relative dependencies between the thermal properties and the viscosity of the HyNPCM. In total, the improved thermal properties and the heat storage potential of the HyNPCM has facilitated them to be considered as a viable candidate for the cool thermal energy storage applications in buildings without sacrificing energy efficiency.

14/03370 Review of utilization of extended surfaces in heat transfer problems

Nagarani, N. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 604–613.

This review presents when and how extended surfaces with heat exchanger have been used over the past 15 years in the field of heat transfer. They have been used in this field for over 100 years, but their use has increased recently. For the past 10 years many industries required high-performance heat transfer components with lower weight, volume and cost. The reported investigations are categorized into five major groups as follows: annular fins, elliptical fins and elliptical tube, pin fins, longitudinal fins and recent trend fins by experimental, numerical and analytical methods. Around 70 published articles related to fins with heat exchangers are reviewed briefly. This information is useful for the future use of the different shapes of extended surfaces based on space availability and cost.

14/03371 Review of water-heating systems: general selection approach based on energy and environmental aspects

Ibrahim, O. *et al. Building and Environment*, 2014, 72, 259–286.

Water heating contributes an important proportion of residential energy consumption globally. Different kinds of domestic hot-water production systems exist and the operational cost, environmental effect and performance of these systems differ according to various energy sources, climates, system types and system designs. Hence, the proper choice of a domestic hot-water system could save energy, protect nature and significantly reduce operational costs. This paper illustrates, to the best of the author's knowledge, the existing water-heating systems along with the principle, advantages, disadvantages and state-of-the-art for each. Six different categories were presented, namely wood, oil/gas, electric, heat pump, solar and instantaneous systems. The heat-pump systems were further classified into several groups, namely air source, ground source, solar assisted, ground source-solar assisted, photovoltaic–thermal and gas-engine driven systems. In addition, concerning solar water heating, different types of systems and collectors were presented and reviewed. Principal conclusions from the review are outlined and a general approach to recommend the appropriate water-heating system is proposed. The main conclusions included the following. Instantaneous water heaters work on a demand principle and thus need to use their energy source (gas/oil/electricity) when hot water is required without hot-water storage. High instantaneous heating energy is needed to provide the required hot-water temperature. Using gas or oil as the energy source causes local pollution and obliges the use of a continuous fuel supplying system. Continuous electricity supply is needed for electric-based heaters. In the case of frequent power outages for grid-connected homes or off-grid homes, storing electrical energy in sufficient capacity batteries is required. Accordingly, in the case of non-continuous electrical power supply, the instantaneous electrical system should be disregarded. Wood, oil and gas domestic storage-type water heaters are potential alternatives in the absence of sufficient electrical energy supply. However, they are not preferred due to the production of local pollution which may be harmful to the residents' health. Concerning the use of phase changer materials in solar domestic hot-water systems, contradictory results have been reported by different researchers; hence, it is recommended to await further technical and research development before judging this technology.

14/03372 Simulated and experimental performance of split packaged air conditioner using refrigerant HC-290 as a substitute for HCFC-22

Padalkar, A. S. *et al. Applied Thermal Engineering*, 2014, 62, (1), 277–284.

This paper discusses the use of propane (HC-290) as a safe and energy efficient alternative to HCFC-22 in a typical split air conditioner with nominal cooling capacities up to 5.1 kW. Initially, split air conditioner performance is simulated for cooling capacity, energy efficiency ratio (EER), and refrigerant charge. Tests were conducted for different test cases in a psychrometric test chamber with HCFC-22 and HC-290. The test conditions considered are as per Indian Standards, IS 1391 (1992) Part I. The various parameters considered were based on simulated performance with the objective to achieve maximum EER for the desired cooling capacity. As the flammability is an issue for HC-290, the reduction of HC-290 charge was another objective. Two different types of condensers, first with smaller size tubing and another parallel flow condenser (PFC) or minichannel condenser were used in order to reduce HC-290 charge. For HC-290, the highest EER achieved was 3.7 for cooling capacity 4.90 kW for a refrigerant charge of 360 g. The important safety aspects of using HC-290 in air conditioner are discussed. The refrigerant charge as per EN 378 for different cooling capacities and room sizes is also considered.

14/03373 Simultaneous integration, control and enhancement of both fluid flow and heat transfer in small scale heat exchangers: a numerical study

Léal, L. *et al. International Communications in Heat and Mass Transfer*, 2013, 49, 36–40.

Compactness, efficiency and control of heat exchangers are of great interest in many processes. A technological breakthrough must be achieved to go further in their ability to respond to needs. A new concept for the heat exchanger is proposed. It consists in dynamically deforming at least one of the walls of a low hydraulic diameter channel. Heat transfer and mass flow rate enhancements are investigated in single-phase flow. When the deformation is a progressive wave with a relative amplitude of 98.5% and frequency of 50 Hz, it generates a flow

having a mass velocity of up to 510 $kg\,m^{-2}\,s^{-1}$. Although the Reynolds number is low the heat transfer coefficient is enhanced by up to 450% compared to a straight channel.

14/03374 The melting process of storage materials with relatively high phase change temperatures in partially filled spherical shells

Archibold, A. R. *et al. Applied Energy*, 2014, 116, 243–252.

A two-dimensional axisymmetric model of the heat transfer and fluid flow during the melting process inside a spherical latent heat thermal storage capsule is analysed. A void space was provided within the capsule to take into account the volumetric expansion of the phase change material (PCM). The mathematical model was solved using the finite-volume method, and the enthalpy-porosity formulation was employed to solve the energy equations in both the liquid and solid regions of the PCM. The effects of the Grashof and Stefan numbers on the thermal performance of the capsules of various diameters (20, 30, 40 and 50 mm) have been investigated. It was found that increasing the Grashof number from 1.32×10^4 to 2.06×10^5 enhances the heat transfer. Also for a constant Grashof number (9.09×10^4) the PCM melts at a faster rate when the Stefan number increases from 0.077 to 0.097. Finally, appropriate dimensionless variables based on a combination of the Fourier, Grashof and Stefan numbers are introduced in order to obtain a generalized correlation for the liquid mass fraction and the Nusselt number during melting of sodium nitrate.

14/03375 Thermal conductivities of actinides (U, Pu, Np, Cm, Am) and uranium-alloys (U–Zr, U–Pu–Zr and U–Pu–TRU–Zr)

Kim, Y. S. *et al. Journal of Nuclear Materials*, 2014, 445, (1–3), 272–280.

The thermal conductivity correlations of actinides (U, Pu, Np, Cm, Am) and alloys of U–Zr, U–Pu–Zr and U–Pu–TRU–Zr were developed for the use in TRU burning reactors as a function of temperature and alloy composition, using the available data in the literature and extrapolating information obtained in the literature. Because of the scarcity in the measured data for thermal conductivities of TRU elements in the literature, estimations for the thermal conductivities of Pu, Am, Np, and Cm were made. A correlation for U–Zr alloy was also developed and extended to U–Pu–Zr and U–Pu–TRU–Zr alloys.

14/03376 Thermal evaluation of nanofluids in heat exchangers

Anoop, K. *et al. International Communications in Heat and Mass Transfer*, 2013, 49, 5–9.

Nanofluids, suspensions of nanoparticles (<100 nm) in a base fluid, have shown enhanced heat transfer characteristics. In this study, the thermal performances of nanofluids in industrial-type heat exchangers are investigated. Three mass particle concentrations of 2%, 4% and 6% of silicon dioxide–water (SiO_2–water) nanofluids are formulated by dispersing 20 nm diameter nanoparticles in distilled water. Experiments are conducted to compare the overall heat transfer coefficient and pressure drop of water versus nanofluids in laboratory-scale plate and shell-and-tube heat exchangers. Experimental results show both augmentation and deterioration of heat transfer coefficient for nanofluids depending on the flow rate and nanofluid concentration through the heat exchangers. This trend could be explained by the counter effect of the changes in thermophysical properties of fluids together with the fouling on the contact surfaces in the heat exchangers. The measured pressure drop while using nanofluids show an increase when compared to that of basefluid which could limit the use of nanofluids in industrial applications.

14/03377 Thermal management of a multiple mini-channel heat sink by the integration of a thermal responsive shape memory material

Di Maio, E. *et al. Applied Thermal Engineering*, 2014, 62, (1), 113–122.

In this paper, a novel application of a thermo-responsive shape memory polymer (SMP) is proposed to smart-control the forced flow of water in a multi mini-channel heat sink. In particular, it is reported that millimetre-sized cylinders made of SMP could be used to smartly obstruct the fluid flow by adapting the flow cross section to the heat load to be removed. By integrating the sensing, the control and the actuation functions within a unique, millimetre-sized device, these micro-valves, unlike the traditional actuators normally used for flow control, could be easily embedded into small heat sinks, with significant space and energy saving, useful, in particular, in systems where several miniaturized components have to be cooled concurrently, such as the modern mainframes or the concentrated photovoltaic solar cells. Two possible configurations for the SMP were considered in this study: an 'open' configuration, without any obstruction of the water flow free and an 'obstructed' configuration, with the millimetre-sized cylinder partially occupying the mini-channel. A numerical, steady state analysis was carried out with water in single-phase forced convection, to determine the effect of these two states on the internal fluid flow characteristics under different conditions of heat flux and pressure drop and to evaluate the overall thermal behaviour of the smart-controlled multiple mini-channel heat sink in terms of ability to control the temperature of the system and to reduce the energy consumption.

14/03378 Thermal property measurement and heat storage analysis of $LiNO_3$/KCl-expanded graphite composite phase change material

Huang, Z. *et al. Applied Energy*, 2014, 115, 265–271.

A $LiNO_3$/KCl-expanded graphite (EG) composite phase change material (PCM) was prepared for solar thermal energy storage application at high temperature (~200 °C). In such composite material, eutectic system $LiNO_3$/KCl is characterized by high-phase change latent heat and EG serves as the heat transfer promoter. Investigations by means of differential scanning calorimetry, hot disk analyser and heat storage performance tests in a latent thermal energy storage unit were devoted to the thermal property measurement and heat storage performance analysis of the $LiNO_3$/KCl–EG composite. Experimental results revealed that the melting temperature of the composite material was close to that of the eutectic $LiNO_3$/KCl, and the phase change latent heat ranging from 142.41 to 178.10 J/g was dependent on its mass fraction of EG. The thermal conductivities of the composites were 1.85–7.56 times higher compared with the eutectic $LiNO_3$/KCl, and the conductivity value varied with the EG mass content and the apparent density of the composite. In addition, the heat transfer in the composite material during the heat storage process was enhanced through the thermal conductivity improvement, while the heat storage duration was affected by the phase change latent heat and the apparent density of the composite material.

14/03379 Titanium dioxide nanofluids for heat transfer applications

Saleh, R. *et al. Experimental Thermal and Fluid Science*, 2014, 52, 19–29.

In recent study, the transport properties, namely the thermal conductivity and viscosity, were studied experimentally for titanium dioxide nanoparticles dispersed in distilled water. The data are collected for particle volumetric concentration up to 1.0% and the temperature range of the measurements was from 10 to 60 °C. The results showed that the thermal conductivity increased with increasing volumetric concentration and also with increasing temperature. The data obtained from the measurements were compared with several existing theoretical models. However, the data do not reveal a good agreement with the classical as well as Brownian motion theoretical model. Furthermore, the effect of the nanofluid on the thermal performance of heat pipes is investigated experimentally. The wall temperature distribution and the thermal resistance between evaporation and condensation section are measured and compared with those for the heat pipes using distilled water. The influence of charge volume ratio of working fluid, inclination angle of the heat pipe and the amount of nanoparticles dispersed in distilled water on thermal performance of heat pipes are considered. It is found that the inclination of 45° and 60% charge volume ratio of working fluid corresponds to the best thermal performance of heat pipe using distilled water as well as titanium dioxide nanofluids.

11 ENGINES

Power generation and propulsion, electrical vehicles

14/03380 An assessment of regulated emissions and CO_2 emissions from a European light-duty CNG-fueled vehicle in the context of Euro 6 emissions regulations

Bielaczyc, P. *et al. Applied Energy*, 2014, 117, 134–141.

Natural gas is one of the most promising alternative fuels to meet the upcoming stringent Euro 6 emissions regulations in the European Union, as well as the planned reductions in CO_2 emissions. For spark-ignition engines, bi-fuel fuelling equipment is widely available and engine conversion technology for European automobiles is well established, thereby facilitating usage of natural gas in its compressed form (CNG). In light of the promising characteristics and increasing usage of natural gas as a vehicular fuel, this study investigates emissions from a passenger car featuring a spark-ignition engine capable of running on both CNG and standard gasoline. Results from

emissions testing of the vehicle on a chassis dynamometer are presented and discussed in the context of the Euro 6 emissions requirements. The test vehicle featured a multipoint gas injection system and was an unmodified, commercially available European vehicle meeting the Euro 5 standard. The results indicated that when fuelled with CNG, such a vehicle can comfortably meet Euro 6 emissions limits, with certain differences observed in the emissions according to the fuel type used. Furthermore, when running on CNG the vehicle was observed to emit considerably less CO_2 than when fuelled with gasoline, with the reduction closely agreeing with the results of other studies.

14/03381 DNS with detailed and tabulated chemistry of engine relevant igniting systems

Bekdemir, C. *et al*. *Combustion and Flame*, 2014, 161, (1), 210–221.

Developments in modern engine technology are moving towards a regime with fuel injection uncoupled from combustion. Auto-ignition is an essential characteristic in these systems. The accurate prediction of this chemical process is of paramount importance. Tabulation techniques can provide a detailed chemistry description which is needed to represent the subtle processes that occur during ignition. Strictly, only chemical sources are stored in a look-up table, while assumptions have been made about the mixing process in this pre-processing step. In this study, the validity of flamelet generated manifolds (FGMs) in a series of canonical configurations representative for compression ignition combustion processes is investigated using direct numerical simulation (DNS). To this purpose, the FGM approach is applied to 0D perfectly stirred reactor (PSR), igniting 1D counterflow diffusion flame (CD-flame) and igniting 2D mixing layer simulations for a wide range of relevant engine conditions. An FGM table generated with homogeneous reactor simulations is able to correctly predict reaction progress in PSR cases which include mixing. On the other hand, an FGM table generated with a single igniting CD-flame at a constant strain rate predicts the trend in auto-ignition delay for varying strain rates qualitatively correct. Ignition in a 2D mixing layer, where a straining field due to vortical structures exists, is also well predicted with this FGM. To improve the quantitative auto-ignition prediction near the ignition limit, an extra controlling variable is needed.

14/03382 Effects of fuel compensation in transitional cycles on the smoothness of combustion mode switching in a diesel engine

Shi, L. *et al*. *Fuel Processing Technology*, 2014, 118, 55–63.

In this paper, the effects of a fuel injection compensation strategy on the smoothness in the compression-ignition (CI)–homogeneous charge compression ignition (HCCI) combustion mode switching process at equal load were studied because indicated mean effective pressure (IMEP) fluctuation often occurs in diesel HCCI engines during the conventional CI combustion mode and HCCI combustion mode switching process. The fuel compensation in one transitional cycle, two transitional cycles and three transitional cycles were discussed, and the return maps of the IMEP variation were analysed. The results showed that the fuel increase of the first transitional cycle can enhance the combustion of this cycle and prevent the IMEP from decreasing. More transitional cycles with decreased fuel compensation ratio can improve the smoothness of the IMEP. However, the magnitude of the decreasing trend of the IMEP fluctuation ratio decreases and the fuel control strategy becomes complicated as the number of transitional cycles increases. The fuel injection compensation strategy for the diesel engine is optimized when two transitional cycles and fuel ratios of 1.07 for the first cycle and 1.03 for the second cycle are used, and the fluctuation of the IMEP decreased by 68% compared to the direct combustion mode switching process.

14/03383 Effects of gaseous ammonia direct injection on performance characteristics of a spark-ignition engine

Ryu, K. *et al*. *Applied Energy*, 2014, 116, 206–215.

The effects of direct injection of gaseous ammonia on the combustion characteristics and exhaust emissions of a spark-ignition engine were investigated. Port-injection gasoline was used to enhance the burning of ammonia that was directly injected into the engine cylinder. Appropriate direct injection strategies were developed to allow ammonia to be used in spark-ignition engines without sacrifice of volumetric efficiency. Experimental results show that with gasoline providing the baseline power of 0.6 kW, total engine power could increase to 2.7 kW when the injection timing of ammonia was advanced to 370 before top dead centre (BTDC) with injection duration of 22 ms. Engine performance with use of gasoline–ammonia was compared to that with gasoline alone. For operations using gasoline–ammonia, with baseline power from gasoline at 0.6 kW the appropriate ammonia injection timing was found to range from 320 to 370 BTDC for producing 1.5–2.7 kW. The peak pressures were slightly lower than those using gasoline alone because of the lower flame of ammonia, resulting in reduction of cylinder pressure. The brake specific energy consumption (BSEC) with gasoline–ammonia was very similar to that with gasoline alone. Ammonia direct injection caused slight reductions of brake specific carbon monoxide for all the loads studied but significantly increased brake specific hydrocarbons because of the reduced combustion temperature of ammonia combustion. The use of ammonia resulted in increased NO_x emissions because of formation of fuel NO_x. Ammonia slip was also detected in the engine exhaust because of incomplete combustion.

14/03384 Electrical consumption of two-, three- and four-wheel light-duty electric vehicles in India

Saxena, S. *et al*. *Applied Energy*, 2014, 115, 582–590.

The Indian government has recently announced the national electric mobility mission plan, which sets ambitious targets for electric vehicle (EV) deployment in India. One important barrier to substantial market penetration of EVs in India is the impact that large numbers of EVs will have on an already strained electricity grid. Properly predicting the impact of EVs on the Indian grid will allow better planning of new generation and distribution infrastructure as the EV mission is rolled out. Properly predicting the grid impacts from EVs requires information about the electrical energy consumption of different types of EVs in Indian driving conditions. This study uses detailed vehicle powertrain models to estimate per kilometre electrical consumption for electric scooters, three-wheelers and different types of four-wheelers in India. The powertrain modelling methodology is validated against experimental measurements of electrical consumption for a Nissan Leaf car. The model is then used to predict electrical consumption for several types of vehicles in different driving conditions. The results show that in city driving conditions, the average electrical consumption is: 33 Wh/km for the scooter, 61 Wh/km for the three-wheeler, 84 Wh/km for the low power four-wheeler, and 123 Wh/km for the high power four-wheeler. For highway driving conditions, the average electrical consumption is: 133 Wh/km for the low power four-wheeler, and 165 Wh/km for the high power four-wheeler. The impact of variations in several parameters are modelled, including the impact of different driving conditions, different levels of loading by air conditions and other ancillary components, different total vehicle masses, and different levels of motor operating efficiency.

14/03385 Estimating the influence of intermittent operation on the change of life of a gas turbine

Aminov, R. Z. and Kozhevnikov, A. I. *Electric Power Systems Research*, 2014, 107, 153–157.

It is important that the life of flexible energy equipment be accurately assessed, as knowledge about the pace of life reduction can aid in optimizing the operating conditions for long- and short-term planning purposes. This paper describes a method for assessing the change in life of a gas turbine with start/stop cycles and working in off-design modes. The method was applied to several types of gas turbine equipment from manufacturers and research companies. As an example, calculations of three different loading modes for a week are presented. This method could also be applied to steam turbines and equipment with combined cycles.

14/03386 Exponential weighted method and a compromise programming method for multi-objective operation of plug-in vehicle aggregators in microgrids

Carpinelli, G. *et al*. *International Journal of Electrical Power & Energy Systems*, 2014, 56, 374–384.

Distribution networks are undergoing radical changes due to the high level of penetration of dispersed generation and storage systems. This trend is strongly modifying the structure as well as the management of distribution networks, which are progressively approaching the new concept of microgrids (MGs). Also, the level of penetration of storage systems for plug-in electric vehicles (PEVs) is increasing significantly due to the significant potential that PEVs have for reducing both emission levels and transportation costs. The inclusion of these vehicles in MGs leads to a series of challenges in grid operation, especially ensuring the provision of services that can improve the operation of distribution networks. This paper deals with MGs, including renewable generation plants and aggregators of PEV fleets connected to the grid through power electronic devices. A multi-objective optimization model is presented for obtaining optimal, coordinated operation of MGs. A multi-objective model was solved using two different methods, i.e. the exponential weighted criterion method and a compromise programming method. Both of these methods appeared to be particularly suitable when computational time is an important issue, as it is in the case of optimal control. The effectiveness of the multi-objective approach was demonstrated with numerical applications to a low-voltage MG; other multi-objective model-solving algorithms also were assessed in order to compare their programming complexity and the computational efforts required.

14/03387 Influence of the structure of water-in-fuel emulsion on diesel engine performance
Attia, A. M. A. and Kulchitskiy, A. R. *Fuel*, 2014, 116, 703–708.
In this paper, the effect of the structure of water-in-diesel fuel emulsion (WFE) on a three-cylinder diesel engine performance has been investigated. Based on membrane emulsification, two different membranes of pore sizes of 0.2 and 0.45 μm has been individually used to change the emulsion structure while keeping the same WFE volumetric content (at 17% water volumetric content and 0.5% mixing emulsifier content). The results showed that emulsions with large size of water droplets resulted in greater reduction in NO_x emissions up to 25%. While, emulsions with finer droplets not only gave reductions in engine smoke and unburned hydrocarbons of values greater than 80% and 35%, respectively, but also resulted in an increase of the engine effective efficiency up to 20%.

14/03388 Insights into the combustion chemistry within a gas-turbine driven auxiliary power unit as a function of fuel type and power level using soot nanostructure as a tracer
Wal, R. L. V. *et al. Fuel*, 2014, 115, 282–287.
Particulate emissions were collected from an auxiliary power unit (APU) directly on transmission electron microscope grids for particle characterization by high-resolution transmission electron microscopy. Carbonaceous emissions from two fuels, a coal-based Fischer–Tropsch and standard JP-8 were compared, each at three power levels. Differences in soot nanostructure, specifically fullerenic content, reveal changes in the combustion chemistry with engine power level, as do differences in aggregate size between the two fuels. As inferred from the soot nanostructure, comparison between fuels demonstrates the impact of fuel structure on soot formation chemistry.

14/03389 Methods to achieve HCCI/CAI combustion at idle operation in a 4VVAS gasoline engine
Chen, T. *et al. Applied Energy*, 2014, 116, 41–51.
Homogeneous charge compression ignition (HCCI) combustion, also known as controlled auto-ignition (CAI), has been shown to reduce substantially NO_x emissions and fuel consumption in gasoline engines. However, it is still confronted with the problem of its limited operation range. One of the focuses of the current HCCI combustion research is to expand its low load limit to the idle operation. The main obstacle in developing HCCI idle combustion is to avoid misfire due to high dilution and low charge temperature. In this work, research was carried out on a single cylinder engine equipped with fully variable valve lifts and timing devices in order to identify the appropriate engine control strategies to extend the HCCI low load limit. Negative valve overlap (NVO) with port fuel injection and direct gasoline injection were investigated for achieving the appropriate environment for auto-ignition at idle and the optimal tradeoff between the combustion stability and fuel consumption. The result shows that the early intake valve opening (EIVO) strategy is most conductive to produce stable combustion at low load conditions. HCCI operation range was successfully extended to idle condition by employing EIVO strategy at the stoichiometric air–fuel ratio. Good combustion stability can be achieved at 800 rpm, 85 kPa NIMEP condition. In addition, the fuel consumption could be improved further by introducing direct injection together with the EIVO strategy. The analyses demonstrate that the idle HCCI operation was enabled by the stratified residual gas and temperature distribution in the cylinder associated with the EIVO strategy. Furthermore, fuel-reforming processes from the direct gasoline injection into the hot residual gas could reduce dependence on the stratification at low loads.

14/03390 Optimal operating conditions for wet ethanol in a HCCI engine using exhaust gas heat recovery
Saxena, S. *et al. Applied Energy*, 2014, 116, 269–277.
This study explores optimal operating conditions for power generation from wet ethanol in a homogeneous charge compression ignition (HCCI) engine using exhaust gas heat recovery. Wet ethanol is a difficult fuel to ignite as it requires high compressed gas temperatures to achieve ignition causing the requirement for substantial intake charge heating. A heat exchanger is retrofitted to a HCCI engine in this study to recover excess heat from the exhaust gases to provide the energy input for intake charge heating. This study builds on prior experimental research by focusing on optimal operating conditions for wet ethanol in HCCI with exhaust gas heat recovery. Operating points include intake pressures of 1.8 and 2.0 bar absolute, equivalence ratios of 0.50 and 0.55, combustion timings from just before top dead centre to misfire, and fuel mixtures from 70% to 100% ethanol (with water being the balance). The results suggest that the best operating conditions for the HCCI engine and heat exchanger system in terms of high power output, low ringing, and low nitrogen oxide emissions occur with high intake pressures, high equivalence ratios and highly delayed combustion timing. With a 2 bar absolute intake pressure, an equivalence ratio of 0.55, and a combustion timing near 8 crank angle degrees after top dead centre, 70% ethanol produced a power output of nearly 7.25 bar gross indicated mean effective pressure with low ringing and low nitrogen oxide emissions. This operating point was sustained by using heat transfer from hot exhaust gases into the intake charge, and thus no external heat addition was required – a substantial improvement over prior studies.

14/03391 Performance and emissions of an automotive diesel engine using a tire pyrolysis liquid blend
Martínez, J. D. *et al. Fuel*, 2014, 115, 490–499.
A tyre pyrolysis liquid (TPL) fuel produced in a continuous auger reactor on pilot scale was blended at 5 vol.% (5TPL) with commercial diesel fuel (100D) and tested in a four-cylinder, four-stroke, turbocharged, intercooled, 2.0 L Nissan diesel automotive engine (model M1D) with common-rail injection system. The engine performance and exhaust emissions were obtained for both the 5TPL blend and the commercial diesel fuel. Experiments were conducted in four operating modes that simulate the New European Driving Cycle. Both brake-specific fuel consumption and brake-thermal efficiency seemed to be deteriorated by the composition and the properties of the TPL blend at low engine load, while at higher engine load the values of these parameters were almost equal for both fuels. Total hydrocarbon emissions followed the same pattern than that of the specific fuel consumption since they were higher for 5TPL at low engine load but similar for both fuels when the engine load increased. NO_x emissions were higher for 5TPL than those for 100D in three operating modes (U10, EU8 and EU16), while no significant differences were found in the other mode (U9). In addition, 5TPL led to higher smoke opacity respect to those found for 100D in all operating modes. Combustion duration was slightly longer for 5TPL than 100D. This work could be considered as a contribution for strengthening and encouraging the waste tyre pyrolysis for the production of liquid fuels which could be used in automotive engines in very limited concentrations.

14/03392 Temperature and thermal stress analyses of a ceramic-coated aluminum alloy piston used in a diesel engine
Cerit, M. and Coban, M. *International Journal of Thermal Sciences*, 2014, 77, 11–18.
This study determines both temperature and thermal stress distributions in a plasma-sprayed magnesia-stabilized zirconia coating on an aluminium piston crown to improve the performance of a diesel engine. Effects of the coating thickness on temperature and thermal stress distributions are investigated, including comparisons with results from an uncoated piston by means of the finite element method. Temperature and thermal stress analyses are performed for various coating thicknesses from 0.2 to 1.6 mm excluding the bond coat layer. Temperature at the coated surface is significantly higher than that of the uncoated piston. It is observed that the coating surface temperature increases with coating thickness by decreasing rate. Increase in the maximum temperature according to the uncoated piston is 64.3% for 1.0 mm thick coating. The higher combustion chamber temperature provided by means of coating results in the better thermal efficiency of the engine. It also provides for a reduction in the substrate surface temperature. The normal stress on the coated surface decreases with increasing coating thickness. Maximum normal stress occurs on the bond coat surface. Its value is approximately two and three times greater than substrate and coating surfaces respectively. Maximum shear stress occurs on the bond coat surface and its magnitude is nearly double that of the substrate surface.

Hybrid engine systems

14/03393 A novel approach for state of charge estimation based on adaptive switching gain sliding mode observer in electric vehicles
Chen, X. *et al. Journal of Power Sources*, 2014, 246, 667–678.
In this paper, a novel approach for battery state of charge (SOC) estimation in electric vehicles (EVs) based on an adaptive switching gain sliding mode observer (ASGSMO) has been presented. To design the ASGSMO for the SOC estimation, the state equations based on a battery equivalent circuit model (BECM) are derived to represent dynamic behaviours of a battery. Comparing with a conventional sliding mode observer, the ASGSMO has a capability of minimizing chattering levels in the SOC estimation by using the self-adjusted switching gain while maintaining the characteristics of being able to compensate modelling errors caused by the parameter variations of the BECM. Lyapunov stability theory is adopted to prove the error convergence of the ASGSMO for the SOC estimation. The lithium-polymer battery is utilized to conduct experiments for determining the parameters of the

BECM and verifying the effectiveness of the proposed ASGSMO in various discharge current profiles including EV driving conditions on both city and suburban roads.

14/03394 Approximate Pontryagin's minimum principle applied to the energy management of plug-in hybrid electric vehicles

Hou, C. *et al. Applied Energy*, 2014, 115, 174–189.

This paper proposes an optimal energy management strategy based on the approximate Pontryagin's minimum principle (A-PMP) algorithm for parallel plug-in hybrid electric vehicles (HEVs). When the driving cycles are known in advance, Pontryagin's minimum principle (PMP) can help to achieve the best fuel economy, but real-time control has been unavailable due to the massive computational load required by instantaneous Hamiltonian optimization. After observing some regular patterns in numeric PMP results, the authors were inspired to apply a novel piecewise linear approximation strategy by specifying the turning point of the engine fuel rate for the Hamiltonian optimization. As a result, the instantaneous Hamiltonian optimization becomes convex. Considering the engine state, there are only five candidate solutions for the optimization. For the engine off state, only one of the available torque split ratios (TSR) is one of these five candidates. The other four TSR candidates are for the engine on state, including the TSR when the engine operates at the best efficiency point for the current speed, the TSR when the engine delivers all the required torque and two terminal TSRs. The optimal TSR is the one with the smallest Hamiltonian of the current engine state. The engine state with the smallest Hamiltonian will be requested for the next time step. The results show that the A-PMP strategy reduced fuel consumption by 6.96% compared with the conventional 'all-electric, charge-sustaining' strategy. In addition, the A-PMP shortened the simulation time from 6 h to only 4 min, when compared with the numeric PMP method. Unlike other approximation methods, the proposed novel piecewise linear approximation caused no severe distortion to the engine map model. The engine state switching frequency is also reduced by 43.40% via both the filter and the corresponding engine on/off optimal control strategy.

14/03395 Emissions and fuel economy for a hybrid vehicle

Taymaz, I. and Benli, M. *Fuel*, 2014, 115, 812–817.

Conventional vehicles play a large role in city transportation all over the world. These vehicles run on energy obtained from fossils fuels such as petroleum oils that pollute the environment with the gases that are emitted after burning. In addition, the cost of this fuel type will increase because of decreasing reserves; therefore, these petroleum oils must be used very efficiently. Due to environmental and financial problems, the development of clear and efficient city transportation has accelerated. Hence, hybrid electrical vehicles gain significant importance because they are environmentally friendly and efficient in fuel usage. In this study, a conventional commercial vehicle was chosen for design to a mixed hybrid systems. A simulation programme was created for road simulation of these vehicles and with acceleration included; the consumption and emission values were also approximately calculated. As a result, it was seen that the mixed hybrid vehicles possess the same performance values with low fuel and CO_2 emissions.

14/03396 Experimental investigation of thermal balance of a turbocharged SI engine operating on natural gas

Gharehghani, A. *et al. Applied Thermal Engineering*, 2013, 60, (1–2), 200–207.

This paper experimentally investigates the thermal balance and performance of a turbocharged gas spark ignition engine. The first law of thermodynamics was used for control volume around the engine to compute the output power, transferred energy to the cooling fluid, exhaust gases and also unaccounted losses through convection and radiation heat transfer. Thermal balance tests were performed for various operational conditions including full and half loads and different cooling fluid temperatures. Results indicate that by increasing engine load and coolant temperature, the percentage of transferred energy to the exhaust gases increased while the percentage of coolant energy decreased. Also, experimental data reveals that using gaseous fuel and a turbocharger in the engine leads to 4.5% and 4% more thermal efficiency than gasoline and natural aspirated, respectively. Also, second law analysis reveals that using a turbocharger leads to a 3.6% increase in exergetic efficiency of the engine, averagely. Based on experimental results, an empirical correlation was suggested for computing the energy of exhaust gases which shows good agreement with the experimental data for the majority of operating conditions.

14/03397 Influence of operating conditions on the optimum design of electric vehicle battery cooling plates

Jarrett, A. and Kim, I. Y. *Journal of Power Sources*, 2014, 245, 644–655.

The efficiency of cooling plates for electric vehicle batteries can be improved by optimizing the geometry of internal fluid channels. In practical operation, a cooling plate is exposed to a range of operating conditions dictated by the battery, environment, and driving behaviour. To formulate an efficient cooling plate design process, the optimum design sensitivity with respect to each boundary condition is desired. This determines which operating conditions must be represented in the design process, and therefore the complexity of designing for multiple operating conditions. The objective of this study is to determine the influence of different operating conditions on the optimum cooling plate design. Three important performance measures were considered: temperature uniformity, mean temperature and pressure drop. It was found that of these three, temperature uniformity was most sensitive to the operating conditions, especially with respect to the distribution of the input heat flux, and also to the coolant flow rate. An additional focus of the study was the distribution of heat generated by the battery cell: while it is easier to assume that heat is generated uniformly, by using an accurate distribution for design optimization, this study found that cooling plate performance could be significantly improved.

14/03398 Modeling and energy management control design for a fuel cell hybrid passenger bus

Simmons, K. *et al. Journal of Power Sources*, 2014, 246, 736–746.

This paper presents the modelling and supervisory energy management design of a hybrid fuel cell/battery-powered passenger bus. With growing concerns about petroleum usage and greenhouse gas emissions in the transportation sector, finding alternative methods for vehicle propulsion is necessary. Proton exchange membrane (PEM) fuel cell systems are viable possibilities for energy converters due to their high efficiencies and zero emissions. It has been shown that the benefits of PEM fuel cell systems can be greatly improved through hybridization. In this work, the challenge of developing an on-board energy management strategy with near-optimal performance is addressed by a two-step process. First, an optimal control based on Pontryagin's minimum principle (PMP) is implemented to find the global optimal solution which minimizes fuel consumption, for different drive cycles, with and without grade. The optimal solutions are analysed in order to aid in development of a practical controller suitable for on-board implementation, in the form of an auto-regressive moving average (ARMA) regulator. Simulation results show that the ARMA controller is capable of achieving fuel economy within 3% of the PMP controller while being able to limit the transient demand on the fuel cell system.

14/03399 Performance of a 4-cylinder diesel engine running on tire oil–biodiesel–diesel blend

Bulent Koc, A. and Abdullah, M. *Fuel Processing Technology*, 2014, 118, 264–269.

The objective of this research was to investigate the performance of a four-cylinder, light-duty compression ignition engine fuelled with the binary and ternary blends of tyre oil, biodiesel and certified #2 diesel fuels. The tyre oil was produced from scrap tyres via pyrolysis and pretreated before blending with biodiesel and diesel fuels. The fuel blends contained 5% and 10% tyre oil. The power, torque and brake specific fuel consumption, and the exhaust emissions of oxides of nitrogen (NO_x), carbon dioxide (CO_2), and carbon monoxide (CO) were determined from the constant speed engine tests at full throttle. Blending 10% tyre oil with 10% biodiesel and 80% diesel fuel produced the highest torque and power outputs, and reduced the brake specific fuel consumption significantly. The NO_x and CO emissions from the tyre oil (10%) containing a ternary fuel blend were significantly lower than the biodiesel (10%)–diesel (90%) binary fuel. Recycling the scrap tyres to produce tyre oil via pyrolysis is a promising method for reducing the impact of this waste material to the environment. Once pretreated by filtering and desulfurization, tyre oil can be used as an alternative fuel for diesel engines.

Transport battery development

14/03400 A high-capacity lithium–air battery with Pd modified carbon nanotube sponge cathode working in regular air

Shen, Y. *et al. Carbon*, 2013, 62, 288–295.

This study reports a lithium–air battery with a freestanding, highly porous Pd-modified carbon nanotube (Pd–CNT) sponge cathode. The Pd-CNT sponge was synthesized through a chemical vapour deposition growth followed with an electrochemical deposition process. To build a whole lithium–air battery, the air cathode is integrated with a ceramic electrolyte-protected lithium metal anode and non-volatile ionic liquid electrolyte. The lithium anode is stable during the operation and long-time storage and the ionic liquid is chemically inert. By controlling the amount of ionic liquid electrolyte, the sponge is wet but not fulfilled by the electrolyte. Such configuration offers a tri-continuous passage for lithium ions, oxygen and electrons, which is propitious to the discharge reaction. In addition, the existence of Pd nanoparticles improves the

catalytic reactivity of the oxygen reduction reaction. The battery is durable to any humidity level and delivers a capacity as high as $9092\,mA\,h\,g^{-1}$.

14/03401 A numerical model for a soluble lead-acid flow battery comprising a three-dimensional honeycomb-shaped positive electrode

Oury, A. *et al. Journal of Power Sources*, 2014, 246, 703–718.

A novel reactor design is proposed for the soluble lead-acid flow battery, in which a three-dimensional honeycomb-shaped positive PbO_2-electrode is sandwiched between two planar negative electrodes. A two-dimensional stationary model is developed to predict the electrochemical behaviour of the cell, especially the current distribution over the positive structure and the cell voltage, as a function of the honeycomb dimensions and the electrolyte composition. The model includes several experimentally based parameters measured over a wide range of electrolyte compositions. The results show that the positive current distribution is almost entirely determined by geometrical effects, with little influence from the hydrodynamic. It is also suggested that an increase in the electrolyte acidity diminishes the overvoltage during discharge but leads at the same time to a more heterogeneous reaction rate distribution on account of the faster kinetics of PbO_2 dissolution. Finally, the cycling of experimental monocells is performed and the voltage response is in fairly good accordance with the model predictions.

14/03402 Analysis of alternative policy instruments to promote electric vehicles in Austria

Gass, V. *et al. Renewable Energy*, 2014, 61, 96–101.

The large amount of CO_2 emissions and of fossil fuel consumption caused by the transportation sector makes the sector central for attaining the European Union (EU) energy and climate policy targets. Consequently, new propulsion systems are developed in the automotive industry, which currently have cost disadvantages compared to conventional internal combustion engines (ICE). The paper provides a review on support measures for electric vehicles (EV), which have been currently implemented within the EU. In a case study analysis for Austria, different policy instruments were analysed including a CO_2 tax aimed at supporting the introduction of electric vehicles in Austria. The authors have calculated and compared total costs of ownership (TCO), which includes all costs associated with the ownership of a car including costs of purchasing, operating and maintaining, charges and taxes as well as costs of recycling and disposal. A survey on main specifications of electric vehicles has been conducted among the main automobile manufacturers and importers in Austria. Based on this survey, TCO have been calculated dynamically from 2011 to 2020 for a business-as-usual scenario considering currently implemented taxes and subsidies for ICE and electric vehicle systems. Three alternative policy support measures have been assessed to promote EV until 2015. The results show that EV will be cost-competitive with ICE by the year 2012/2013 if projected production volumes and thus economies of scale are reached. Further, it was concluded that an up-front price support seems to be favourable over taxation systems.

14/03403 Effect of battery state of charge on fuel use and pollutant emissions of a full hybrid electric light duty vehicle

Duarte, G. O. *et al. Journal of Power Sources*, 2014, 246, 377–386.

The research described in this paper focuses on evaluating the effect of battery state of charge (SOC) in the fuel consumption and gaseous pollutant emissions of a Toyota Prius full hybrid electric vehicle, using the vehicle specific power methodology. Information on SOC, speed and engine management was obtained from the on-board diagnostic interface, with additional data collected from a five-gas analyser and global positioning system receiver with barometric altimeter. Compared with average results, 40–50% battery SOC presented higher fuel consumption (57%), as well as higher CO_2 (56%), CO (27%) and NO_x (55.6%) emissions. For battery SOC between 50% and 60%, fuel consumption and CO_2 were 9.7% higher, CO was 1.6% lower and NO_x was 20.7% lower than average. For battery SOC between 60% and 70%, fuel consumption was 3.4% lower, CO_2 was 3.6% lower, CO was 6.9% higher and NO_x was 24.4% higher than average. For battery SOC between 70% and 80%, fuel consumption was 39.9% lower, CO_2 was 38% lower, CO was 33.9% lower and NO_x was 61.4% lower than average. The effect of engine off periods was analysed for CO and NO_x emissions. For off periods higher than 30 s, increases of 63% and 73%, respectively, were observed.

14/03404 Electric propulsion system for electric vehicular technology: a review

Kumar, L. and Jain, S. *Renewable and Sustainable Energy Reviews*, 2014, 29, 924–940.

In recent decades, factors such as the growing concern for pollution-induced climate change, increasingly stringent emission norms for vehicles and depleting petroleum resources, coupled with volatility in their prices, have motivated and accelerated development of sustainable and clean alternatives for transportation systems. Electrification of vehicular technology (EVT) is considered as a promising and sustainable alternative for future transportation systems. In the evolution of EVT, instability of fuel price, fuel economy, range, performance and costs are the governing factors and prime concerns for researchers, vehicle manufacturers and customers. These factors are decided by the design of the electric propulsion system (EPS) for vehicle applications and its suitable integration with various electrical and mechanical components. In this paper, a comparative overview of EVT along with a comprehensive analysis of EPS and a brief discussion on power flow control and management algorithms for EVT is presented. The paper also highlights the on-going technological advancements and future challenges in the roadmap of EPS for the electrification of vehicle technologies.

14/03405 Generic dynamic model of rechargeable batteries

Milocco, R. H. *et al. Journal of Power Sources*, 2014, 246, 609–620.

There are numerous models of rechargeable batteries in the current literature. Some of them are complicated electrochemical approaches; others are given by simple analogies. However, simple models with electrochemical states capable of describing important quantities, like the rate capacity effect and the recovery effect, are hard to find. In this paper, based on an electrochemical approach, the authors present a generalized model suitable for use in battery management systems applications, which takes into account explicitly the rate capacity effect and the state of charge. Moreover, the model is thought up for general energy storage processes based on mass transport and charge transfer. The proposed general model approach is able to interpret the most commonly used models in the literature.

14/03406 Hybrid electric vehicles and their challenges: a review

Hannan, M. A. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 135–150.

There are a number of alternative energy resources being studied for use in hybrid vehicles in preparation of replacing the exhausting supply of petroleum. The use of fossil fuels in vehicles is a rising concern due to their harmful environmental effects. Among other sources, batteries, fuel cells, supercapacitors and photovoltaic cells, are studied for vehicle applications. Combinations of these sources of renewable energies can be used in hybrid electric vehicle (HEVs) for the next generation of transportation. Various aspects and techniques of HEVs from the energy management system (EMS), power conditioning and propulsion system are explored in this paper. Other related fields of HEVs such as DC machines and vehicle systems are also included. Various types of models and algorithms derived from simulations and experiments are explained in detail. The performance of the various combinations of HEV systems are summarized. This paper provides a survey of HEVs and their source combinations, models, EMS, etc. From the review, it is observed that the existing technologies are more or less capable of powering HEVs well; however, the reliability and intelligent systems are still not up to the mark. Accordingly, this review has highlighted many factors, challenges and problems in sustainable next-generation hybrid vehicles.

14/03407 Model predictive control-based power dispatch for distribution system considering plug-in electric vehicle uncertainty

Su, W. *et al. Electric Power Systems Research*, 2014, 106, 29–35.

As an important component of a smart grid, advanced plug-in electric vehicles (PEVs) are drawing much more attention because of their high-energy efficiency, low carbon and noise pollution, and low operational cost. Unlike other controllable loads, PEVs can be connected with the distribution system anytime and anywhere according to the customers' preference. The uncertain parameters (e.g. charging time, initial battery state-of-charge, start/end time) associated with PEV charging make it difficult to predict the charging load. Therefore, the inherent uncertainty and variability of the PEV charging load have complicated the operations of distribution systems. To address these challenges, this paper proposes a model predictive control (MPC)-based power dispatch approach. The proposed objective functions minimize the operational cost while accommodating the PEV charging uncertainty. Case studies are performed on a modified IEEE 37-bus test feeder. The numerical simulation results demonstrate the effectiveness and accuracy of the proposed MPC-based power dispatch scheme.

14/03408 Modeling and adaptive control for supercapacitor in automotive applications based on artificial neural networks

Eddahech, A. *et al. Electric Power Systems Research*, 2014, 106, 134–141.

The behaviour of a supercapacitor is a complex and non-linear function of its current rate, temperature, chemistry and history, and hence cannot easily be determined. In this study, a one-layer feed-forward

artificial neural network was used, trained using the back-propagation algorithm, to model the behaviour of supercapacitors used in automotive applications. Possible improvements of the neural network model using a multilevel approach are discussed. Then, on the basis of this model, a neural controller is developed in order to control the supercapacitor voltage. Simulation results confirmed the accuracy of the model compared to measurements from supercapacitor module power-cycling.

14/03409 Review on the heat dissipation performance of battery pack with different structures and operation conditions

Xu, X. M. and He, R. *Renewable and Sustainable Energy Reviews*, 2014, 29, 301–315.

This paper reviews the heat dissipation performance of a battery pack with different structures (including longitudinal battery pack, horizontal battery pack and changing the position of air-inlet and air-outlet) and operation conditions [including: state of charge (SOC) state, charge and discharge rate, and practical operation condition]. The average thermal power of 55 Ah lithium-ion battery monomer decreases along with increasing environment temperature, SOC state decreasing and charge and discharge rate falling. The maximum temperature increase and temperature difference of the battery pack are not only relevant to the flow rate, but also related to the airflow duct structure. A battery pack with air inlets on both sides is more conducive to forced air cooling. The flow rate of a battery pack at 70% SOC state is maximum. The maximum temperature increase and temperature difference of a battery pack at 70% SOC state are minimal and that of 90% SOC state are maximum. The flow rate and the average pressure drop between the air inlet and air outlet both decrease along with increasing charge and discharge rate, but the maximum temperature increase and temperature difference of the battery pack increase. Considering the practical operational conditions of battery packs, the charge and discharge rate is between 0.5 and 0.8 C, and the maximum temperature increase and maximum temperature difference of a battery pack are 7.61 and 4.29 °C. The reference basis for heat flow field characteristic analysis and structure design of battery pack are also given.

14/03410 Statistical analysis for understanding and predicting battery degradations in real-life electric vehicle use

Barré, A. *et al. Journal of Power Sources*, 2014, 245, 846–856.

This paper describes the statistical analysis of recorded data parameters of electrical battery ageing during electric vehicle use. These data permit traditional battery ageing investigation based on the evolution of the capacity fade and resistance raise. The measured variables are examined in order to explain the correlation between battery ageing and operating conditions during experiments. Such study enables us to identify the main ageing factors. Then, detailed statistical dependency explorations present the responsible factors on battery ageing phenomena. Predictive battery ageing models are built from this approach. Thereby results demonstrate and quantify a relationship between variables and battery ageing global observations, and also allow accurate battery ageing diagnosis through predictive models.

14/03411 Thermal and energy battery management optimization in electric vehicles using Pontryagin's maximum principle

Bauer, S. *et al. Journal of Power Sources*, 2014, 246, 808–818.

Depending on the actual battery temperature, electrical power demands, in general, have a varying impact on the life span of a battery. As electrical energy provided by the battery is needed to temper it, the question arises at what temperature which amount of energy optimally should be utilized for tempering. Therefore, the objective function that has to be optimized contains both the goal to maximize life expectancy and to minimize the amount of energy used for obtaining the first goal. In this paper, Pontryagin's maximum principle is used to derive a causal control strategy from such an objective function. The derivation of the causal strategy includes the determination of major factors that rule the optimal solution calculated with the maximum principle. The optimization is calculated offline on a desktop computer for all possible vehicle parameters and major factors. For the practical implementation in the vehicle, it is sufficient to have the values of the major factors determined only roughly in advance and the offline calculation results available. This feature sidesteps the drawback of several optimization strategies that require the exact knowledge of the future power demand. The resulting strategy's application is not limited to batteries in electric vehicles.

12 REFRACTORIES/ CERAMICS

Properties, production, applications

14/03412 Cryogenic mechanical properties of woven glass/epoxy composites modified with multi-walled carbon nanotube and *n*-butyl glycidyl ether under tensile static and cyclic loadings

Takeda, T. *et al. Cryogenics*, 2013, 58, 33–37.

This paper investigates the mechanical properties of woven glass/epoxy composites modified with multi-walled nanotube and *n*-butyl glycidyl ether under tensile static and cyclic loadings at cryogenic temperatures. Tensile tests were conducted at liquid nitrogen temperature (77 K), and the tensile properties of the composites were evaluated. Tension–tension fatigue tests were also performed on the composites at 77 K in order to assess their fatigue performance. Failed specimens were examined by microscopy to verify the failure mechanisms.

14/03413 Durability of self-cleaning TiO_2 coatings on fired clay brick façades: effects of UV exposure and wet & dry cycles

Graziani, L. *et al. Building and Environment*, 2014, 71, 193–203.

Environmental pollution is constantly increasing and it causes aesthetical concerns to urban buildings exposed to the atmosphere. Nanometric titanium dioxide (TiO_2) has become a promising photocatalytic material owing to its ability to accelerate degradation of many organic contaminants. Application of TiO_2 is rising and it found application on building industry. However, photocatalytic properties of this nanotechnology strongly depend on substrate morphology and on its nature. Thus, it is not correct to extrapolate photocatalytic activity on different types of substrate. Moreover, very few information is available about effectiveness of TiO_2 coatings after aging phenomena when applied on different substrate. This paper aims to investigate the photocatalytic properties of TiO_2 applied on clay brick surfaces both after deposition and after aging process. TiO_2 characterization was carried out by assessing nano-film morphology, wettability and self-cleaning efficiency before durability test. Self-cleaning ability was also evaluated during aging test in order to evaluate its variation in long-term applications. Results show that photocatalytic efficiency of TiO_2 remain stable after aging, thus TiO_2 shows a good photocatalytic efficiency when it is applied to clay brick substrate. In the long run, photocatalytic efficiency of clay brick specimens treated with TiO_2 is seven times higher than untreated specimens.

14/03414 Effect of Mach number on thermoelectric performance of SiC ceramics nose-tip for supersonic vehicles

Han, X.-Y. and Wang, J. *Applied Thermal Engineering*, 2014, 62, (1), 141–147.

This paper focuses on the effects of Mach number on thermoelectric energy conversion for the limitation of aero-heating and the feasibility of energy harvesting on supersonic vehicles. A model of nose-tip structure constructed with SiC ceramics is developed to numerically study the thermoelectric performance in a supersonic flow field by employing the computational fluid dynamics and the thermal conduction theory. Results are given in the cases of different Mach numbers. Moreover, the thermoelectric performance in each case is predicted with and without Thomson heat, respectively. Due to the increase of Mach number, both the temperature difference and the conductive heat flux between the hot side and the cold side of nose tip are increased. This results in the growth of the thermoelectric power generated and the energy conversion efficiency. With respect to the Thomson effect, over 50% of total power generated converts to Thomson heat, which greatly reduces the thermoelectric power and efficiency. However, whether the Thomson effect is considered or not, with the Mach number increasing from 2.5 to 4.5, the thermoelectric performance can be effectively improved.

14/03415 Experimental analysis of the energy performance of a full-scale PCM glazing prototype

Goia, F. *et al. Solar Energy*, 2014, 100, 217–233.

This paper deals with the development and use of innovative glazing systems that use a phase change material (PCM) to achieve dynamic and responsive behaviour. The coupling of a PCM and glass panes could be a way of improving the low thermal inertia of fenestrations and could be an effective way of collecting, storing and exploiting solar energy at a building scale. In this study, a simple prototype of a PCM glazing system has been proposed and its energy performance has been

analysed and compared with conventional fenestration. The two glazing technologies were installed on a south-facing outdoor test cell in a temperate sub-continental climate. The surface temperatures, transmitted irradiances and heat fluxes of both the PCM glazing and the reference fenestration were measured during an extensive experimental campaign. Summer, mid-season and winter days were considered during the analysis, in both sunny and cloudy weather conditions, in order to assess the energy performance of the PCM glazing under different boundary conditions. The experimental results have highlighted a good ability of the PCM glazing to store solar energy and to smooth and delay peak values of the total heat flux. In summer the PCM prototype allows the energy gain to be lowered by more than 50%, compared to the traditional fenestration. In winter, a suitable reduction in the heat loss during the day can be observed, but the direct solar gain is also drastically reduced and the application of this technology for passive solar heating purpose might not always be effective. The obtained results have pointed out the promising performance of PCM glazing, even though a careful integration of the PCM glazing component with the control strategies of the indoor air temperature (e.g. night cooling) is necessary.

14/03416 Fatigue delamination growth in woven glass/epoxy composite laminates under mixed-mode II/III loading conditions at cryogenic temperatures

Takeda, T. *et al. Cryogenics*, 2013, 58, 55–61.

This study investigates the cryogenic delamination growth behaviour in woven glass-fibre reinforced polymer composite laminates under mixed-mode II/III fatigue loading. Fatigue delamination tests were conducted with six-point bending plate specimens at room temperature, liquid nitrogen temperature (77 K) and liquid helium temperature (4 K), and the delamination growth rate data for various mixed-mode ratios of modes II and III were obtained. The energy release rate was evaluated using the three-dimensional finite element method. In addition, the fatigue delamination growth mechanisms were characterized by scanning electron microscopic observations of the specimen fracture surfaces.

14/03417 Neutronic evaluation of a PWR with fully ceramic microencapsulated fuel. Part I: lattice benchmarking, cycle length, and reactivity coefficients

Brown, N. R. *et al. Annals of Nuclear Energy*, 2013, 62, 538–547.

The fully ceramic microencapsulated (FCM) fuel concept is based on the tri-isotropic (TRISO) carbon-coated fuel particles. These particles were developed and demonstrated for use in high-temperature gas reactors. It has been proposed to use these particles in light water reactors to provide potential operational and safety benefits. The reference fuel in this case assumes TRISO-like particles with a ~20%-enriched uranium–nitride kernel embedded in a silicon carbide (SiC) matrix. The fuel particles are contained in a 'compact' which is then inserted into a cladding. The fuel assembly features the same dimensions as a standard 17×17 Westinghouse fuel assembly. FCM fuel requires fission products to traverse several barriers in the proposed fuel design before reaching the cladding. FCM fuel may also reduce fuel-cladding interaction and fuel pellet swelling while enabling higher fuel burn-up. This study is a neutronic evaluation of the use of FCM fuel in an advanced pressurized water reactor. On the lattice level, the SERPENT Monte Carlo and TRITON deterministic tools were used, while the whole core simulation was based on the three-dimensional PARCS nodal code. This paper presents the results of the lattice-level neutronic study of doubly heterogeneous FCM fuel. Strong agreement was found between the SERPENT and TRITON codes in terms of k-infinity as a function of burn-up, actinide build-up, and 'pin' powers. The impact of several simplifying geometric assumptions was considered, such as the use of a square particle lattice within the FCM fuel pins. It was determined that the linear reactivity model does not provide a good estimate of the fuel cycle length, due primarily to non-linear reactivity behaviour at high burn-up (>800 effective full power days). To determine cycle length, higher order reactivity models were applied to the lattice results. The calculated cycle lengths are slightly reduced versus a reference uranium oxide case. Finally, the assembly-level reactivity coefficients were calculated as a function of burn-up. The fuel and moderator temperature coefficients were negative for FCM fuel, but reduced in magnitude by approximately 50% versus a reference uranium oxide case.

14/03418 Neutronic evaluation of a PWR with fully ceramic microencapsulated fuel. Part II: nodal core calculations and preliminary study of thermal hydraulic feedback

Brown, N. R. *et al. Annals of Nuclear Energy*, 2013, 62, 548–557.

The fully ceramic microencapsulated (FCM) fuel is based on the tri-isotropic (TRISO) carbon coated fuel particles. These particles were developed and demonstrated for use in high-temperature gas reactors. It has been proposed to use these particles in light water reactors to provide potential operational and safety benefits. The reference fuel in this case assumes TRISO-like particles with a ~20%-enriched uranium-nitride kernel embedded in a silicon carbide (SiC) matrix. The fuel particles are contained in a 'compact' which is then inserted into a cladding. The fuel assembly features the same dimensions as a standard 17×17 Westinghouse fuel assembly. FCM fuel requires fission products to traverse several barriers in the proposed fuel design before reaching the cladding. FCM fuel may also reduce fuel-cladding interaction and fuel pellet swelling while enabling higher fuel burn-up. This study is a neutronic evaluation of the use of FCM fuel in an advanced pressurized water reactor (PWR). On the lattice level, the SERPENT Monte Carlo and TRITON deterministic tools were used, while the whole core simulation was based on the three-dimensional PARCS nodal code. The present paper focuses on two of the issues associated with this proposed implementation: specifically the development of a reasonable reference full-core model of an advanced PWR with FCM fuel and the response of the PWR to a reactivity insertion accident (RIA). This work addresses the issues of the increased power density and transients that occur on short time-scales in a PWR. In this case, the RIA takes the form of a control rod ejection for a typical PWR reactor. This results in a sudden increase in power and a corresponding increase in fuel kernel temperature. In the case of a PWR, this response is more demanding than in the case of a gas-cooled reactor, because the kinetic parameters and feedback coefficients of the two reactors are quite different. The parameters for the fuel and matrix material in the PARCS thermal–hydraulic module were modified to reflect the different geometry and materials. Preliminary data for both un-irradiated and irradiated SiC were obtained from the literature and included in the analyses. A super prompt critical RIA produces an average energy deposition (<124.6 J/g) that is estimated for different simplified thermal representations of the FCM fuel pin.

14/03419 On characterization and measurement of average solar field mirror reflectance in utility-scale concentrating solar power plants

Zhu, G. *et al. Solar Energy*, 2014, 99, 185–202.

Due to the emerging need for the development of acceptance test codes for commercial concentrating solar power (CSP) plants, an effort is made here to develop a mirror reflectance model suitable for CSP applications as well as a general procedure to measure the average mirror reflectance of a solar field. Typically, a utility-scale solar field includes hundreds of thousands of mirror panels (if not more), and their reflectance is subject to many factors, such as weather and planned washing schedule. The newly developed mirror reflectance model can be used to characterize different types of mirror materials and can be directly used to perform optical performance evaluation of solar collectors. The newly proposed procedure for average solar field reflectance measurements includes a baseline comprehensive measurement and an individual factor measurement: the former allows a comprehensive survey of mirror reflectance across the whole solar field, and the latter can provide correcting factors for selected individual factors to further improve the accuracy of the baseline measurements. A detailed test case implementing the general procedure is applied to a state-of-the-art commercial parabolic trough plant and validates the proposed mirror reflectance model and average reflectance measurement procedure. In the test case, the plant-wide reflectance measurements at a commercial utility-scale solar plant were conducted and can shed light on relevant analysis of CSP applications. The work can also be naturally applied to other types of solar plants, such as power towers and linear Fresnel plants.

14/03420 Optimum glass fiber volume fraction in the adhesive for the Al-SUS adhesively bonded joints at cryogenic temperatures

Bang, C. S. *et al. Composite Structures*, 2014, 108, 119–128.

The tight control of adhesive thickness in large bonding areas such as the secondary barrier of a cargo containment system for liquefied natural gas carriers or floaters is difficult and expensive although the adhesive thickness is a dominant parameter to determine the bonding performance of adhesively bonded joint, especially at cryogenic temperatures. Therefore, the method for improving bonding strength and fracture toughness for thick adhesive layer was investigated by reinforcing the adhesive layer with glass fibre mat for the robust and sustainable system design for the secondary barrier. A randomly oriented E-glass fibre mat was used as reinforcement for the film-type epoxy adhesive. The lap shear strength and fracture behaviour were investigated with respect to fibre volume fraction, and compared to those of the adhesive without reinforcement. The effects of repeated thermal shocks on adhesive bonding performances of adhesive joints with reinforced adhesive were also studied. The experimental results revealed that the randomly oriented glass fibre reinforcement improved much the bonding strength and fracture toughness of adhesive even with 1.0 mm thickness at the cryogenic temperature. Also it was found that the enhancement of bonding performances strongly depended on the coefficient of thermal expansion differences

between the stainless steel foil and reinforced adhesive. Finally an optimum volume fraction of the glass fibre reinforcement was proposed for the newly developed Al–SUS adhesively bonded joint.

14/03421 Passive performance of glazed components in heating and cooling of an open-space office under controlled indoor thermal comfort

Cappelletti, F. *et al. Building and Environment*, 2014, 72, 131–144.

According to Fanger's comfort theory, the individual thermal sensation is mainly connected with the thermal balance of the human body. This balance and the related comfort indicators [the predicted mean vote (PMV) and the correlated predicted percentage of dissatisfied] depend on four environmental parameters (air temperature, humidity and velocity, and internal envelope mean radiant temperature) and two variables connected with the human being (physical activity and clothing). Different to the other environmental parameters under the system control, the mean radiant temperature is strongly conditioned by the envelope characteristics, and in particular, by the presence of glazed surfaces whose insulating performance is commonly lower than the one of opaque components. Transparent components also admit solar radiation into the indoor environment, affecting the thermal balance of the building and of the occupants. In this paper, the heating and cooling energy needs of an open-space office with different windows' characteristics have been analysed under controlled internal comfort conditions. A set of configurations given by different windows' glazing systems, area, disposition and orientation has been simulated, considering the climatic conditions of Paris, Milan and Rome. The passive energy performance of the different glazing solutions has then been compared accounting for the long-term comfort conditions (on seasonal basis). The time distribution of the PMV and the discomfort time weighted by the predicted percentage of dissatisfied are analysed, including also the effect of the diffuse and beam solar radiation directly reaching the occupants through the windows.

14/03422 Relaxor ferroelectric and photo-electrochemical properties of lead-free $Ba_{1-x}Eu_{2x/3}(Ti_{0.75}Zr_{0.25})O_3$ ceramics. Application to chromate reduction

Boutal, N. *et al. Solar Energy*, 2014, 99, 291–298.

The perovskite $Ba_{1-x}Eu_{2x/3}Ti_{0.75}Zr_{0.25}O_3$ ($x = 0.025$, 0.05) have been prepared by solid-state reaction. A dielectric study on ceramics performed in the ranges of temperature (77–500 K) and frequency (10^2–2×10^5 Hz) reveal typical relaxor behaviour and diffuse phase transition. The relaxor parameters (T_m, ΔT_m, $\Delta\varepsilon_r'/\varepsilon_r'$) decrease slightly with the increase of Eu-dopant concentration. The dielectric relaxation rate follows the Vogel–Fulcher relation with activation energy of 21 meV, an attempt frequency $f_o = 1.1 \times 10^8$ Hz and a static freezing temperature $T_f = 95$ K for $x = 0.025$. An optical gap of 2.25 eV is obtained from the diffuse reflectance spectrum. The photo-electrochemistry throws light on the nature of the electronic bands. The Mott–Schottky plot is characteristic of *n*-type conduction from which a flat band potential of −0.60 V_{SCE} and an electrons density of 1.2×10^{18} cm^{-3} are determined for the composition $x = 0.025$. The upper valence band located at 6.4 eV below vacuum is made up of O^{2-}: *2p* orbital whereas the conduction band consists of empty *3d* levels (4.13 eV) with a high reducing ability. The energetic diagram clearly assesses the photoactivity of the perovskite. The performance is improved when the crystallite size becomes comparable with the length of the nanodomains. As application, 95% of chromate (10^{-4} M) is reduced after 6 h of exposition to sunlight (AM1).

14/03423 Resistance to He^{2+} induced irradiation damage in metallic glass $Zr_{64}Cu_{17.8}Ni_{10.7}Al_{7.5}$

Wang, B. *et al. Journal of Nuclear Materials*, 2014, 444, (1–3), 342–348.

This paper used He^{2+} ion-irradiated metallic glass $Zr_{64}Cu_{17.8}Ni_{10.7}Al_{7.5}$ and metallic W with an energy of 500 keV at fluences of 2×10^{17}, 5×10^{17}, 1×10^{18} and 2×10^{18} ions/cm^2. Zr-based metallic glass remained mainly amorphous at different fluences. At the irradiation fluence of 2×10^{18} ions/cm^2, there was a channel-like damage layer appeared within the range of the surface ions. Cracking and peeling along the grain boundary occurred on the surface of metallic W at the fluence of 1×10^{18} ions/cm^2; or even multi-layer peeling occurred at the fluence of 2×10^{18} ions/cm^2. TEM analysis revealed that there were a lot of helium bubbles at the end of the range of helium ion. The connection and coalescence growth process of a helium bubble was observed. The surface rms roughness ρ_{rms} of Zr-based metallic glass increased first and then decreased with the increase in fluence. The resistance to He^{2+} irradiation in Zr-based metallic glass was superior to the one in metallic tungsten.

14/03424 Self-cleaning glass prepared from a commercial TiO_2 nano-dispersion and its photocatalytic performance under common anthropogenic and atmospheric factors

Cedillo-González, E. I. *et al. Building and Environment*, 2014, 71, 7–14.

Nowadays, a wide range of self-cleaning building materials or colloidal solutions for the fabrication of photocatalytic coatings are already commercially available. However, some practical limitations still restrict their widespread use in the building sector. For example, in normal household conditions, photocatalytic building materials are exposed to factors that can compromise their efficiency or promote the release of nanoparticles to the environment. In addition, most of the building materials are commonly exposed to atmospheric variables that may greatly differ depending on the geographical zone or the season of the year. In this work, TiO_2 films prepared from a commercially available dispersion of nanoparticles were deposited over soda-lime glass substrates. The effects of (i) NaCl residues from the TiO_2 nano-dispersion; (ii) treatment with model solutions that simulate the environmental and domestic weathering; (iii) the relative humidity and (iv) the substrate temperature on the photocatalytic activity versus stearic acid were evaluated. The obtained results indicate that these films are more efficient in environments with low humidity levels and relatively high temperatures. Therefore, their commercialization in dry and hot geographic zones would enable the best performance. Furthermore, it was found that these materials can be applied in houses without appreciable loss of efficiency, due to weathering from common cleaning agents or atmospheric factors, like rain or acid rain.

14/03425 Specific outcomes of the research on the radiation stability of the French nuclear glass towards alpha decay accumulation

Peuget, S. *et al. Journal of Nuclear Materials*, 2014, 444, (1–3), 76–91.

This paper presents an overview of the main results of the French research on the long-term behaviour of SON68 nuclear glass towards alpha decay accumulation. The effect of the radiation damage induced by alpha decay and also helium build-up were investigated by examining glass specimens, doped with a short-lived actinide ^{244}Cm, irradiated by light and heavy ions. Additionally, atomistic simulations by molecular dynamics have provided further information on the atomic-scale effects of the macroscopic phenomena observed. These studies have shown that some macroscopic properties vary with the accumulation of alpha decay, but then stabilize after integrated doses of the order of $4 \times 10^{18}\,\alpha\,g^{-1}$. For example, the glass density diminishes by about 0.6%, its Young's modulus by about 15%, and its hardness by about 30%, while its fracture toughness increases by around 50%. The scanning electron microscopy (SEM) and transmission electron microscopy (TEM) characterization showed that the glass is still homogeneous. No phase separation, crystallization or bubbles formation was noticed up to an alpha decay dose corresponding to several thousand years of disposal of nuclear glass canister. Moreover the initial alteration rate of the glass is not significantly affected by the glass damage induced by alpha decays or heavy ions irradiations. The comparison of the macroscopic evolutions of the Cm-doped glass with those obtained for glasses irradiated with light or heavy ions (from either experimental and molecular dynamic studies) suggests that the macroscopic evolutions are induced by the nuclear interactions induced by the recoil nuclei of alpha decay. The analysis of the behaviour of the glass structure subjected to ballistic effects with various spectroscopic studies, together with the results of atomistic modelling by molecular dynamics, have identified some slight changes in the local order around some cations. Moreover, a modification of the medium-range order has also been demonstrated through changes in the bond angles between network formers and broadening of the ring size distributions, indicating increasing disorder of the glass structure. This structural evolution induced by alpha decays would be driven by the reconstruction of the glass disorganized by displacement cascades of the recoil nuclei, freezing a glass structure with a higher fictive temperature. This 'ballistic disordering (BD) fast quenching' event induces a new glassy state characterized by a higher enthalpy state. Accumulation of α decays induce similar phenomena of 'BD-fast quenching', increasing the fraction of the sample volume characterized by a 'high enthalpy state'. At dose around $4 \times 10^{18}\,\alpha\,g^{-1}$ the entire sample volume has been affected by 'BD-fast quenching' events at least once, which explain the stabilization of the evolutions of glass structure and properties. Helium behaviour was also studied by measuring the helium solubility constants and diffusion coefficients. Helium atoms are incorporated into the glass-free volume with a solubility constant that varies less than 10% around a value of about 10^{11} at cm^{-3} Pa^{-1} and a density of solubility sites accessible for helium around 2×10^{21} sites cm^{-3} which is larger than helium production in a glass package. Helium diffusion experiments performed on infused and Cm-doped SON68 glasses indicate that helium migration is controlled by a classical thermally activated diffusion process, whose activation energy (e.g. 0.6 ± 0.03 eV) is not affected by an alpha decay dose of around $10^{19}\,\alpha\,g^{-1}$. Helium implantation studies suggest that helium trapping could exist in nanometre-size bubbles. SEM and TEM analysis performed on a Cm-doped glass damaged by an alpha decay dose of around $10^{19}\,\alpha\,g^{-1}$, showed a homogeneous glass without crystallization, phase separation or bubbles with a spatial resolution limit of 10 nm. Bubbles of significant size seem very unlikely to form at room temperatures. But, the ability to form helium bubbles of nanometre size, at

temperature below the glass vitreous transition temperature cannot be excluded. However, all these studies agree on one point, the absence of macroscopic consequence on the glass integrity of accumulation of high helium concentration in the glass.

14/03426 Synthesis and chemical durability of U-doped sphene ceramics

Teng, Y. *et al. Journal of Nuclear Materials*, 2014, 444, (1–3), 270–273.
U-doped sphene ceramics with and without Al as charge compensation, i.e. $Ca_{1-x}U_xTi_{1-2x}Al_{2x}SiO_5$ and $Ca_{1-2y}U_yTiSiO_5$, were prepared by solid-state reaction method. The effects of U content on the phase structure of the ceramics were investigated. The chemical durability of U-doped sphene ceramic waste forms was also examined. The results show that the optimum sintering temperature of the U-doped sphene ceramics is about 1260 °C. For the ceramics with $x \leq 0.065$ or $y \leq 0.045$, the primary crystalline phase is sphene, and a small amount of $CaTiO_3$, SiO_2 phases are also oberved. UO_2 phase appears when $x \geq 0.07$ or $y \geq 0.05$. The solubility of U in $Ca_{1-2y}U_yTiSiO_5$ is lower than that in the samples with Al as charge compensation. Moreover, the normalized elementary release rate of U in both the $Ca_{1-x}U_xTi_{1-2x}Al_{2x}SiO_5$ and $Ca_{1-2y}U_yTiSiO_5$ ceramics decreases with increasing time and remains almost unchanged ($\sim 2 \times 10^{-3}\,g\,m^{-2}\,d^{-1}$) after 28 days, exhibiting high chemical durability. These results suggest that the sphene-based ceramics are promising candidate for the immobilization of actinides.

13 ALTERNATIVE ENERGY SUPPLIES

Biofuels and bioconversion energy

14/03427 A cost-effective integrated process to convert solid-state fermented sweet sorghum bagasse into cellulosic ethanol

Yu, M. *et al. Applied Energy*, 2014, 115, 331–336.
A cost-competitive integrated technology to convert solid-state fermented sweet sorghum bagasse (SS) into cellulosic ethanol which combined ethanol distillation, NaOH pretreatment and simultaneous saccharification and co-fermentation (SSCF) was presented in this study. After solid-state fermentation, the SS was distilled with 10% (w/w dry material, DM) NaOH to separate sugar-based ethanol and pretreat lignocelluose simultaneously in one step and one distillation stripper, then the NaOH pretreated SS was subsequently converted into cellulosic ethanol by SSCF. Results showed that 69.49% ethanol theoretical yield was achieved under the optimal condition based on this novel integrated process. This integrated technology can significantly reduce the energy consumption and capital cost for cellulosic ethanol production, and ensure cellulosic ethanol produced from SS cost-effectively.

14/03428 A phenomenological model of the mechanisms of lignocellulosic biomass pyrolysis processes

Sharma, A. *et al. Computers & Chemical Engineering*, 2014, 60, 231–241.
A comprehensive particle scale model for pyrolysis of biomass has been developed by coupling the reaction mechanisms and transport phenomena. The model, which also accounts for the combined effect of various parameters such as particle shrinkage and drying, was validated using available experimental data from the literature. The validated model was then used to study the effect of operating temperature and biomass particle size, both of which strongly influenced the rate of biomass conversion. For example, for particle sizes less than 1 mm, a uniform temperature throughout the particle was predicted, thus leading to higher conversion rates in comparison to those in the larger particles. On the other hand, any increase in moisture content led to considerable decrease in the rate of biomass conversion. For the operating conditions considered in this study, the volumetric particle shrinkage also increased the decomposition of biomass to end products.

14/03429 Application of the self-heat recuperation technology for energy saving in biomass drying system

Liu, Y. *et al. Fuel Processing Technology*, 2014, 117, 66–74.
An advanced energy-saving drying process based on self-heat recuperation technology was proposed for biomass drying. Compared with previously developed designs, the newly developed design further reduced energy consumption by 40%. Energy consumption in the drying systems was qualified and compared through the process simulator PRO/II. Energy consumption of self-heat recuperative dryers in this study can be reduced to 1/4–1/7 of that of a conventional heat recovery dryer. Effects of the heat exchange type, ratio of air to product, minimum temperature difference between the hot and cold streams in the heat exchanger, and drying medium on the system energy consumption were evaluated when applying self-heat recuperation technology to a biomass drying system.

14/03430 Approaches to greenhouse gas accounting methods for biomass carbon

Downie, A. *et al. Biomass and Bioenergy*, 2014, 60, 18–31.
This investigation examines different approaches for the greenhouse gas (GHG) flux accounting of activities within a tight boundary of biomass C cycling, with scope limited to exclude all other aspects of the lifecycle. Alternative approaches are examined that (a) account for all emissions including biogenic CO_2 cycling – the biogenic method; (b) account for the quantity of C that is moved to and maintained in the non-atmospheric pool – the stock method; and (c) assume that the net balance of C taken up by biomass is neutral over the short-term and hence there is no requirement to include this C in the calculation – the simplified method. This investigation demonstrates the inaccuracies in both emissions forecasting and abatement calculations that result from the use of the simplified method, which is commonly accepted for use. It has been found that the stock method is the most accurate and appropriate approach for use in calculating GHG inventories, however shortcomings of this approach emerge when applied to abatement projects, as it does not account for the increase in biogenic CO_2 emissions that are generated when non-CO_2 GHG emissions in the business-as-usual case are offset. Therefore, the biogenic method or a modified version of the stock method should be used to accurately estimate GHG emissions abatement achieved by a project. This investigation uses both the derivation of methodology equations from first principles and worked examples to explore the fundamental differences in the alternative approaches. Examples are developed for three project scenarios including; landfill, combustion and slow-pyrolysis (biochar) of biomass.

14/03431 Barriers of commercial power generation using biomass gasification gas: a review

Asadullah, M. *Renewable and Sustainable Energy Reviews*, 2014, 29, 201–215.
Gasification is a promising technology to convert biomass into gaseous fuels for distributed power generation. However, the commercial exploitation of biomass energy suffers from a number of logistics and technological challenges. In this review, the barriers in each of the steps from the collection of biomass to electricity generation are highlighted. The effects of parameters in the supply chain management, pretreatment and conversion of biomass to gas, and cleaning and utilization of gas for power generation are discussed. Based on the studies, until recently, the gasification of biomass and gas cleaning are the most challenging parts. Electricity generation, either using engines or gas turbines, requires a stringent specification of gas composition and tar concentration in the product gas. Different types of updraft and downdraft gasifiers have been developed for gasification and a number of physical and catalytic tar separation methods have been investigated. However, the most efficient and popular one is yet to be developed for commercial purposes. In fact, the efficient gasification and gas cleaning methods can produce highly burnable gas with a lower tar content, so as to reduce the total consumption of biomass for a desired quantity of electricity generation. According to a recent report, an advanced gasification method with efficient tar cleaning can significantly reduce the biomass consumption, and thus the logistics and biomass pretreatment problems can ultimately be reduced.

14/03432 Biodiesel production *via* esterification of oleic acid catalyzed by chlorosulfonic acid modified zirconia

Zhang, Y. *et al. Applied Energy*, 2014, 116, 191–198.
Biodiesel is a promising renewable alternative to fossil energy. Biodiesel production from low-cost feedstock involves an essential pretreatment step: esterification of free fatty acids (e.g. oleic acid), for avoiding soap formation and catalyst deactivation. Sulfuric acid modified zirconia (H_2SO_4–ZrO_2) is known to be an effective heterogeneous catalyst for this reaction. However, due to rapid SO_4^{2-} leaching, its reusability is low and its practical use is thus largely hindered. Here, a more stable solid acid analogue is reported for the reaction, chlorosulfonic acid modified zirconia ($HClSO_3$–ZrO_2). It was characterized by X-ray diffraction, scanning electron microscopy, Brunauer–Emmett–Teller, energy dispersive X-ray, infrared, thermogravimetric analysis and NH_3-temperature programmed desorption. Compared with H_2SO_4–ZrO_2, there is over three times more sulfur content and nearly four times more acid sites amount for $HClSO_3$–ZrO_2. More importantly, $HClSO_3$–ZrO_2 demonstrates high catalytic

activity and long durability in esterification of oleic acid, in which the fatty acid methyl ester yield reaches 100% consecutively for at least five cycles under mild conditions.

14/03433 Biodiesel production from yeast *Cryptococcus sp.* using Jerusalem artichoke

Sung, M. *et al. Bioresource Technology*, 2014, 155, 77–83.

Jerusalem artichoke was investigated as a cheap substrate for the heterotrophic production using a laboratory yeast strain *Cryptococcus* sp. Using response surface method, 54.0% of fructose yield was achieved at 12% of dried Jerusalem artichoke powder, 0.57% of nitric acid concentration, 117 °C of reaction temperature, and 49 min of reaction time. At this optimal condition, nitric acid showed the best catalytic activity toward inulin hydrolysis and also the resulting fructose hydrolyte supported the highest microbial growth compared with other acids. In addition, lipid productivity of 1.73 g/L/d was achieved, which is higher than a defined medium using pure fructose as a substrate. Lipid quality was also found to be generally satisfactory as a feedstock for fuel, demonstrating Jerusalem artichoke could indeed be a good and cheap option for the purpose of biodiesel production.

14/03434 Biomass gasification in a downdraft gasifier with a two-stage air supply: effect of operating conditions on gas quality

Galindo, A. L. *et al. Biomass and Bioenergy*, 2014, 61, 236–244.

The gasification of biomass is an attractive technology for the production of electricity, heat, chemicals and liquid fuels. This paper presents an experimental evaluation of the quality of the producer gas in a two-stage, air supply downdraft gasifier, referred to its tar and particle content for different operating conditions. The gas composition and its lower heating value were also determined. Experimental tests were performed varying the operating conditions of the gasifier: the air flow between 18 and 22 N m^3/h (the proximate equivalence ratio from 3.03 to 0.279) and the air flow ratio in the two stages between 0% and 80%, evaluating the effects of these parameters over the quality of the gas. The results show that a fuel gas, with tar and particulate matter content of 54.25 ± 0.66 and 102.4 ± 1.09 mg/N m^3, respectively, was obtained, for a total air flow rate of 20 ± 0.45 N m^3/h and an air ratio, between the two stages, of 80%. For these conditions, the lower heating value of the gas was 4.74 ± 0.5 MJ/N m^3. The two-stage air supply in the gasification allowed to reduce the tar content in the producer gas up to 87% with even a slight increase in the gasifier efficiency. This results can be explained by an increase of the temperatures in the pyrolysis and combustion regions.

14/03435 Comparison of CO_2 and steam gasification reactivity of algal and woody biomass chars

Kirtania, K. *et al. Fuel Processing Technology*, 2014, 117, 44–52.

This study undertook gasification reactivity measurement of an algal biomass (*Chlorella* sp.) char prepared in two different reactors with two gasifying agents (CO_2 and steam) and compared that with similar measurements on woody biomass (commercial wood mix) char in a thermogravimetric analyser at three different temperatures. In general, the woody char from entrained flow reactor showed higher reactivity during gasification. At 800 and 950 °C, similar reactivity was exhibited by algal char from thermogravimetric analyser whereas at 1100 °C, the woody char became more reactive than the algal char. For algae, the char prepared in entrained flow reactor showed lower reactivity than the char from thermogravimetric analyser. The scanning electron microscope images of the char samples showed significant difference in morphology with respect to the char preparation condition and species. For chars of both the species, a temperature of 800 °C and time of around 20 min are found to be sufficient to accomplish most conversion; this information is of practical relevance.

14/03436 Comparison of energy consumption and GHG emissions of open field and greenhouse strawberry production

Khoshnevisan, B. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 316–324.

The greenhouse areas in Iran have expanded rapidly and the greenhouse holders have shown a great tendency to cultivation of those crops that used to be cultivated in open fields. Although, greenhouses are intensive in terms of yield and whole-year production, they are considered being one of the major contributors to greenhouse gases (GHG) emissions in the agricultural sector. In the present study, strawberry cultivation in greenhouses (GH) and open fields (OF) was selected as a representative of those crops which can be grown in both systems. Initial data were randomly collected from 70 OFs and 33 GHs in province of Gilan, Iran. Energy consumption and GHG emissions of two different strawberry production systems were compared. Moreover, energy use efficiency of GH producers due to more energy consumption was studied, then degrees of technical efficiency, pure technical efficiency and scale efficiency were determined using data envelopment analysis. Additionally, the amount of energy inputs wasted in inefficient greenhouses was assessed and energy saving was computed. Furthermore, the effect of energy optimization on GHG emissions was investigated and the total amount of GHG emissions was calculated. The total average of energy input and output was estimated at 35,092.4 and 10,405.9 MJ ha^{-1} for OF production and, similarly, 1,356,932.8 and 137,772.4 MJ ha^{-1} for GH strawberry production. Total GHG emissions were calculated as 803.4 and 35,083.5 kg CO_{2eq} ha^{-1} for OF and GH production, respectively. Based on the evaluations 20.2% (273,902.8 MJ ha^{-1}) of overall energy sources can be saved if the performance of inefficient farmers is enhanced. Optimizing energy in greenhouse production can result in a significant reduction in total GHG emissions and the present emissions of GHG can be reduced to the value of 29309.1 kg CO_{2eq} ha^{-1}.

14/03437 Design and techno-economic evaluation of microbial oil production as a renewable resource for biodiesel and oleochemical production

Koutinas, A. A. *et al. Fuel*, 2014, 116, 566–577.

Experimental results from the open literature have been employed for the design and techno-economic evaluation of four process flowsheets for the production of microbial oil or biodiesel. The fermentation of glucose-based media using the yeast strain *Rhodosporidium toruloides* has been considered. Biodiesel production was based on the exploitation of either direct transesterification (without extraction of lipids from microbial biomass) or indirect transesterifaction of extracted microbial oil. When glucose-based renewable resources are used as carbon source for an annual production capacity of 10,000 t microbial oil and zero cost of glucose (assuming development of integrated biorefineries in existing industries utilizing waste or by-product streams) the estimated unitary cost of purified microbial oil is $3.4/kg. Biodiesel production via indirect transesterification of extracted microbial oil proved more cost-competitive process compared to the direct conversion of dried yeast cells. For a price of glucose of $400/t oil production cost and biodiesel production cost are estimated to be $5.5/kg oil and $5.9/kg biodiesel, correspondingly. Industrial implementation of microbial oil production from oleaginous yeast is strongly dependent on the feedstock used and on the fermentation stage where significantly higher productivities and final microbial oil concentrations should be achieved.

14/03438 Directional overcurrent and earth-fault protections for a biomass microgrid system in Malaysia

Bakar, A. H. A. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 55, 581–591.

Overcurrent protection is intended principally to counteract excessive current in power systems. In distribution systems in Malaysia, non-directional overcurrent protection is adopted because of the radial nature of the power system used. Relays, typically used in distribution network, are designed to cater for current flow in one direction, i.e. from transmission network to load. However, with the forecast increase in generation from renewable sources, it is important that adequate codes are in place with regards to their integration to the sub-transmission/distribution network. The distribution network dynamically changes from a 'passive' to a 'active' network. With distributed generation connected to a distribution network, power flows bi-directionally. Hence, directional overcurrent protection is adopted along the line between the transmission grid and the distributed generation. The bi-directional flow of power also complicates the earth fault protection. This is due to the presence of the distributed generation that will cause the line near the delta side of the transformer still to be energized after the operation of the earth fault relay during a single-phase-to-ground-fault. This paper investigates the directional overcurrent and earth fault protections used to protect the microgrid (biomass generator) in Malaysia. In this study, under-voltage relays are adopted at the delta side of the transformer to fully clear the single-line-to-ground fault which cannot be cleared by earth fault relay. Three-phase-balanced faults and single-line-to-ground-faults at all possible locations in the network have been simulated. Simulation shows good co-ordination and discrimination between overcurrent relays.

14/03439 Energy efficiency and sustainability of complex biogas systems: a 3-level emergetic evaluation

Chen, S. and Chen, B. *Applied Energy*, 2014, 115, 151–163.

Biogas engineering and the biogas-linked agricultural industries as a whole have been used as both a developmental strategy for rural new energy and an important part of renewable agriculture revolution in China. This study proposed a three-level emergetic evaluation framework to investigate the energy efficiency and sustainability of a complex biogas system (CBS) in southern China, comprising agro-industries such as planting, aquaculture, breeding and biogas. The framework is capable of tracking dynamical behaviours of the whole complex system (level I), transformation processes (level II) and resource components (level III) simultaneously. Two new indicators, emergy contribution rate and emergy supply efficiency were developed to address the

contribution and efficiency of resource components within each agro-industrial process. The findings suggested the metabolism of the CBS were increased from 2000 to 2008, in which planting production was the biggest process in terms of total emergy input, while breeding was the most productive one with its highest total emergy yield. The CBS was under an industry transaction process stimulated by biogas construction, while the traditional agricultural activities still play an important role. For economic input, a trend towards a more renewable regime was found behind the total increase over time. With different preferences for renewable or non-renewable resources, planting and aquaculture production were proved natural donation-reliant, while breeding and biogas were economic input-dependent. Among all the economic inputs, electricity, diesels and infrastructure were the most efficient components in supplying all the processes. The challenges for the CBS rested in the relatively high transformities and the constant descent of sustainability within all processes. Armed with the three-level emergetic framework, the status and dynamics of a complex system can be explicitly captured, making it possible to undertake a holistic yet microscopic optimization of biogas-linked production activities.

14/03440 Enzymatic and metabolic activities of four anaerobic sludges and their impact on methane production from ensiled sorghum forage

Sambusiti, C. *et al. Bioresource Technology*, 2014, 155, 122–128.

Biochemical methane potential (BMP) tests were run on ensiled sorghum forage using four inocula (urban, agricultural, mixture of agricultural and urban, granular) and differences on their metabolic and enzymatic activities were also discussed. Results indicate that no significant differences were observed in terms of BMP values ($258 \pm 14\,NmLCH_4\,g^{-1}VS$) with a slightly higher value when agricultural sludge was used as inoculum. Significant differences can be observed among different inocula, in terms of methane production rate. In particular the fastest biomethanization occurred when using the urban sludge (hydrolytic kinetic constant $k_h = 0.146\,d^{-1}$) while the slowest one was obtained from the agricultural sludge ($k_h = 0.049\,d^{-1}$). Interestingly, positive correlations between the overall enzymatic activities and methane production rates were observed for all sludges, showing that a high enzymatic activity may favour the hydrolysis of complex substrate and accelerate the methanization process of sorghum.

14/03441 Extension of energy crops on surplus agricultural lands: a potentially viable option in developing countries while fossil fuel reserves are diminishing

Rahman, M. M. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 108–119.

The rapid depletion of fossil fuel reserves and environmental concerns with their combustion necessitate looking for alternative sources for long-term sustainability of the world. These concerns also appear serious in developing countries which are striving for rapid economic growth. The net biomass growing potential on the global land surface is 10 times more than the global food, feed, fibre and energy demands. This study investigates whether developing countries have sufficient land resources to meet the projected energy demand towards 2035 by planting energy crops on surplus agricultural land after food and feed production. The annual yields of four commonly grown energy crops, specifically jatropha, switchgrass, miscanthus and willow, have been used to make scenarios and estimate land requirements against each scenario. A literature review is carried out on the availability of land resource, past and future trends in land use changes, demand of lands for food production, and potential expansion of croplands. The energy demands towards 2035 are compiled from energy scenarios derived by the International Energy Agency and BP (formerly British Petroleum). This paper also reviewed bio-physiological characteristics of these energy crops to determine whether they are cultivable under tropical climatic conditions in developing regions. This paper found that projected energy demand through 2035 in developing regions could be provided by energy crops grown on a portion of surplus croplands or upgraded grasslands (27% and 22% respectively for the miscanthus scenario). Sustainable land management practices, improved agricultural productivity and adopting suitable energy crops cultivation can potentially supply increasing energy demands.

14/03442 From sugar industry to cane industry: evaluation and simultaneous selection of different types of high biomass canes

Santchurn, D. *et al. Biomass and Bioenergy*, 2014, 61, 82–92.

Sugarcane breeding has traditionally been geared towards maximizing sugar production. The sugarcane crop biomass is now being recognized as an alternative source of renewable energy. The objectives of this study were to characterize and identify different types of high biomass genotypes obtainable from early generation hybrid populations. Sixty potentially high biomass genotypes with variable fibre content were screened from the MSIRI germplasm collection and were evaluated over two harvests. Randomized complete block design was used and four commercial varieties were included for comparison purposes. Based on inherent variations in cane quality and biomass traits, four different types of canes were identified. A selection algorithm was developed that involved culling levels for several traits. The algorithm simultaneously identified 11 high biomass genotypes with variable proportions of sucrose and fibre. The different types of varieties defined should provide additional opportunities to exploit the biomass of sugarcane crop for different end-uses. With minor adjustments to suit local realities, the selection model can be adapted in any sugarcane breeding programme for targeting and exploiting different types of canes.

14/03443 Identifying environmentally and economically optimal bioenergy plant sizes and locations: a spatial model of wood-based SNG value chains

Steubing, B. *et al. Renewable Energy*, 2014, 61, 57–68.

The optimal size and location of bioenergy plants with regards to environmental and economic performance are assessed with a spatially explicit value chain model of the production of synthetic natural gas (SNG) from wood. It consists of several individual models for the availability, harvest, transportation, conversion of wood to SNG, electricity and heat, and the use of these products to substitute non-renewable energy services. An optimization strategy is used to choose the optimal technology configuration for plant sizes from 5 to 200 MW and different locations for any desired weighting between the environmental performance based on life cycle assessment and the economic performance. While the economic optima are found at plant sizes between 100 and 200 MW, the environmental optima are found in the range of 5–40 MW. This trade-off can be minimized at plant sizes above 25 MW according to the presented model. The most important driver of the environmental performance is the efficient substitution of non-renewable energy, which is a site-specific factor. In comparison to this, spatial factors such as wood availability, harvest, and transportation, have a smaller influence on the environmental performance, at least for a country of the size of Switzerland. The main drivers of the economic performance are the revenues from the sale of the SNG plant's products and the SNG production costs, but transportation and wood costs also play a role.

14/03444 Improving biogas production from wheat plant using alkaline pretreatment

Taherdanak, M. and Zilouei, H. *Fuel*, 2014, 115, 714–719.

Alkaline pretreatment of wheat plant (WP), including its grains and straw, was investigated under different conditions in order to enhance biomethane production at mesophilic temperature. Alkaline pretreatment was performed using 8% (w/v) NaOH solution at different temperatures (0, 25, 50, 75 and 100 °C). The best improvement in the yield of methane production was achieved by pretreatment at 75 °C for 60 min, giving a methane yield of $404\,ml\,g^{-1}VS$. The highest glucose content was also obtained under this pretreatment. The cumulative methane yield for pretreated WP at 25, 50 and 75 °C increased the methane yield around 47.5%, 40.8% and 54.5% higher than that of the untreated WP, respectively, while pretreatment at 0 and 100 °C was not effective in improving the biogas production. Qualitative analysis of pretreated WP using scanning electron microscopy and Fourier transform infrared showed the reduction of crystallinity as well as the removal of surface layers of lignin and hemicellulose.

14/03445 In-line monitoring of the transesterification reactions for biodiesel production using NIR spectroscopy

de Lima, S. M. *et al. Fuel*, 2014, 115, 46–53.

In this work, methods for in-line monitoring of the transesterification reactions of soybean oil with methanol using near-infrared (NIR) spectroscopy are developed. Gas chromatography was employed for determining the contents of methyl ester, monoglycerides, diglycerides and triglycerides during the transesterification reaction and used as reference to build partial least squares regression and multiple linear regression calibration models employing NIR spectra. Some preprocessing and variable selection strategies of the spectral data were evaluated. Satisfactory root mean squared error of prediction values were obtained for the external prediction subset. In addition, a multivariate control chart based on latent variables to monitor the progress of the reactions is also presented.

14/03446 Intensification of glycerolysis reaction of higher free fatty acid containing sustainable feedstock using microwave irradiation

Gole, V. L. and Gogate, P. R. *Fuel Processing Technology*, 2014, 118, 110–116.

Glycerolysis can be a useful alternative for the removal of free fatty acid content present in the sustainable feedstock but has limitation in terms of requirement of higher temperatures and higher processing time. In the present work, intensification of glycerolysis has been attempted using microwave irradiations with comparative studies based

on the use of the conventional heating approach. Effect of reaction parameters such as molar ratio (oil to glycerol), catalyst concentration and reaction temperature has been investigated. It has been observed that the optimum molar ratio of oil to glycerol as 1 : 2 and catalyst concentration of 0.1% for both approaches is similar but there is a significant decrease in the reaction time and optimum temperature. Reaction time was reduced from 240 to 25 min while the optimum temperature for maximum benefits reduced from 200 to 105 °C for the microwave-based approach. Comparison based on kinetic analysis confirmed that the rate constant obtained for microwave assisted glycerolysis was six times higher than that obtained in the conventional approach. Energy consumption analysis also revealed the superiority of microwave based synthesis approach with much lower energy requirement for microwave (35.3 kJ/g) as compared to the conventional method (203.6 kJ/g).

14/03447 Investigation of evaporation and engine characteristics of pine oil biofuel fumigated in the inlet manifold of a diesel engine

Vallinayagam, R. *et al. Applied Energy*, 2014, 115, 514–524.

Pine oil biofuel, obtained by the distillation of oleoresins of pine tree, has been chosen as a new renewable fuel for its operation in diesel engine. Notably, the viscosity and cetane number of pine oil was observed to be lower than diesel. The motivation for this work stems from the basic notion that less viscous and lower cetane fuels are considered to be fumigated for their successful operation in diesel engine. As such, pine oil biofuel was vaporized and inducted into the engine cylinder through inlet manifold while diesel was sent through main injection system, providing ignition assistance for the pine oil/air mixture. Prior to conducting engine experiments, the evaporation characteristics of pine oil droplet were studied through suspended droplet experiment so as to get better insights on pine oil droplet evaporation at various temperatures. From this study, it was observed that at higher air temperature (150 °C), evaporation of pine oil was more effective than at lower temperatures (100 and 50 °C) and therefore, 150 °C was chosen as preheat temperature for engine fumigation study. Thus, as a novel attempt, the fundamental study on pine oil droplet evaporation is subtly coupled with engine studies, and the effect of vaporization of pine oil on engine characteristics was mapped. As an outcome of engine study, the maximum percentage of diesel replaced was noticed to be 36% at 100% load and 60% at 20% load. Significantly, the engine performance such as brake specific fuel consumption and brake thermal efficiency was observed to be improved with the increase in proportion of pine oil injection. Further, combustion of fumigated pine oil has been reported to be better, with 36% injection of pine oil showing 10.3% higher in-cylinder pressure than that for 6% injection of pine oil at 100% load.

14/03448 Optimal operating conditions for maximum biogas production in anaerobic bioreactors

Balmant, W. *et al. Applied Thermal Engineering*, 2014, 62, (1), 197–206.

The objective of this paper is to demonstrate the existence of optimal residence time and substrate inlet mass flow rate for maximum methane production through numerical simulations performed with a general transient mathematical model of an anaerobic biodigester introduced in this study. A simplified model is proposed that includes only the most important reaction steps, which are carried out by a single type of microorganisms following Monod kinetics. The mathematical model was developed for a well-mixed reactor (continuous stirred-tank reactor, CSTR), considering three main reaction steps: acidogenesis, with a μ_{max} of 8.64 day^{-1} and a K_S of 250 mg/L, acetogenesis, with a μ_{max} of 2.64 day^{-1} and a K_S of 32 mg/L, and methanogenesis, with a μ_{max} of 1.392 day^{-1} and a K_S of 100 mg/L. The yield coefficients were 0.1-g-dry-cells/g-polymeric compound for acidogenesis, 0.1-g-dry-cells/g-propionic acid and 0.1-g-dry-cells/g-butyric acid for acetogenesis and 0.1 g-dry-cells/g-acetic acid for methanogenesis. The model describes both the transient and the steady-state regime for several different biodigester design and operating conditions. After model experimental validation, a parametric analysis was performed. It was found that biogas production is strongly dependent on the input polymeric substrate and fermentable monomer concentrations, but fairly independent of the input propionic, acetic and butyric acid concentrations. An optimization study was then conducted and optimal residence time and substrate inlet mass flow rate were found for maximum methane production. The optima found were very sharp, showing a sudden drop of methane mass flow rate variation from the observed maximum to zero, within a 20% range around the optimal operating parameters, which stresses the importance of their identification, no matter how complex the actual bioreactor design may be. The model is therefore expected to be a useful tool for simulation, design, control and optimization of anaerobic biodigesters.

14/03449 Photocatalytic depolymerization of rice husk over TiO_2 with H_2O_2

Lu, Y. *et al. Fuel Processing Technology*, 2014, 117, 8–16.

Photocatalytic depolymerization (PCDP) of rice husks over TiO_2 in H_2O_2 aqueous solution under ultraviolet irradiation was investigated. The reaction mixture was fractionated into different extracts by filtration and subsequent sequential extraction with different organic solvents. In total, 172 organic compounds were identified in the extracts with gas chromatography/mass spectroscopy. The compounds can be classified into alkanes, alkenes, arenes, non-substituted alkanols, substituted alkanols, alkenols, phenols, alkanals, alkenals, benzaldehydes, ketones, carboxylic acids, alkanoates, phthalates, nitrogen-containing organic compounds, sulfur-containing organic compounds and other species. Alkanes are the most abundant in the group components. They resulted from the degradation of waxes in rice husks. Aldehydes and ketones were also detected with high relative contents, most of which were derived from cellulose, hemicellulose and waxes. Phthalates and arenes resulted from lignin degradation. Lignin–wax and hemicellulose–wax interlinkages are proposed to be new structures. According to the species identified in the extracts, the mechanisms for photocatalytic oxidation of benzene ring-containing compounds are proposed. The PCDP of rice husks provides an alternative way to obtain value-added chemicals from biomass with low energy consumption and under eco-friendly conditions.

14/03450 Pretreatment of lignocellulosic biomass for enhanced biogas production

Zheng, Y. *et al. Progress in Energy and Combustion Science*, 2014, 42, 35–53.

Lignocellulosic biomass is an abundant organic material that can be used for sustainable production of bioenergy and biofuels such as biogas (about 50–75% CH_4 and 25–50% CO_2). Out of all bioconversion technologies for biofuel and bioenergy production, anaerobic digestion (AD) is a most cost-effective bioconversion technology that has been implemented worldwide for commercial production of electricity, heat, and compressed natural gas from organic materials. However, the utilization of lignocellulosic biomass for biogas production via anaerobic digestion has not been widely adopted because the complicated structure of the plant cell wall makes it resistant to microbial attack. Pretreatment of recalcitrant lignocellulosic biomass is essential to achieve high biogas yield in the AD process. A number of different pretreatment techniques involving physical, chemical, and biological approaches have been investigated over the past few decades, but there is no report that systematically compares the performance of these pretreatment methods for application on lignocellulosic biomass for biogas production. This paper reviews the methods that have been studied for pretreatment of lignocellulosic biomass for conversion to biogas. It describes the AD process, structural and compositional properties of lignocellulosic biomass, and various pretreatment techniques, including the pretreatment process, parameters, performance and advantages vs drawbacks. This paper concludes with the current status and future research perspectives of pretreatment.

14/03451 Promises in direct conversion of cellulose and lignocellulosic biomass to chemicals and fuels: combined solvent–nanocatalysis approach for biorefinary

Dutta, S. and Pal, S. *Biomass and Bioenergy*, 2014, 62, 182–197.

This review surveys sustainable one-pot conversion methods of cellulose into two very important platform chemicals, 5-hydroxymethylfurfural and isosorbide. It is evident that recent developments on the cellulose reactivity and direct conversion of cellulosic and lignocellulosic biomasses into 5-hydroxymethylfurfural (HMF) and fuels in aqueous and ionic liquids medium are essential to meet the future challenges for energy and chemicals. While direct conversion of cellulose into HMF have been demonstrated by using various techniques in aqueous and ionic liquid media. However, for industrial-scale productions, improvements in catalyst design for stability and regeneration ability would be required. Finally, process design to obtain high selectivity is presently the major issue for reducing the complexity of processes and overcoming technical barriers. Suitable synthesis routes for the conversion of cellulose into liquid fuels such as DMF, 5-ethoxymethyl-2-furfural (EMF) and valoric fuels are yet to be developed. Processes developed for the production of DMF with moderate yield via the hydrogenolysis-hydrogenation of HMF have warranted that major challenges remain unsolved. The process of EMF production via the HMF platform is another promising route which is yet to be developed for a scalable production. The HMF and isosorbide derived from cellulose would be essential for future use as feedstock for fuel and building block chemical production. Though direct conversion of cellulose to HMF and liquid fuel candidates are still in the nascent stages of developments for utilizing HMF as industrial scale feedstock, it is hope that this analysis of recent studies in the area will help to pave the way for new research and development.

14/03452 Quantifying the environmental performance of integrated bioethanol and biogas production

Martin, M. *et al. Renewable Energy*, 2014, 61, 109–116.

As the production of biofuels continues to expand worldwide, criticism about the energy output versus input and the competition with food, for example, has been questioned. However, biofuels have the possibility to be optimized in order to improve their environmental performance. This could be accomplished through the use of concepts from industrial symbiosis. This paper provides a quantification of the environmental performance of industrial symbiosis in the biofuel industry through integration of biogas and ethanol processes using a life cycle approach. Results show that although increasing integration is assumed to produce environmental benefits, not all impact categories have achieved this and the results depend on the allocation methods, energy system and assumptions chosen.

14/03453 Saturated monoglyceride effects on low-temperature performance of biodiesel blends

Chupka, G. M. *et al. Fuel Processing Technology*, 2014, 118, 302–309.

The effect of saturated monoglyceride (SMG) content of four B100s on the cloud point (CP) of blends with four diesel fuels was examined. Detecting CP with a more sensitive light-scattering method allowed observation of an early (higher temperature) CP in blends containing approximately 0.01–0.03 wt% SMG. Blend samples with SMG content in this range may be particularly prone to unexpected filter clogging above the measured CP. Results for a 140 blend sample matrix revealed that SMG content had a larger effect on CP than other blend properties. An increase of 0.01 wt% SMG in a biodiesel blend increased CP by as much as 4 °C. At a constant SMG level, increasing biodiesel content lowered CP, as did increasing the diesel fuel aromatic content, by improving the solubility of SMG. This implies that lowering the SMG content of a B100 allows preparation of higher biodiesel content blends having the same or lower CP. Increasing the unsaturated monoglyceride-to-SMG ratio by blending in monoolein lowered CP, presumably because mono-olein inhibits nucleation of SMG. In most blends with SMG content above 0.01 wt%, polymorphic phase transformation of crystallized SMG (converting from the metastable α-form to the less soluble, stable β-form) was observed.

14/03454 Study on the solubilization capacity of bio-oil in diesel by microemulsion technology with Span80 as surfactant

Wang, X.-l. *et al. Fuel Processing Technology*, 2014, 118, 141–147.

Bio-oils obtained from liquefaction/pyrolysis of biomass have undesired properties such as high water content (15–25 wt%), high oxygen content (low heating value), high corrosiveness (acidity) and instability. Therefore, they cannot be directly adopted for fuel applications. Solubilizing bio-oil in diesel by microemulsion technology is one of the most convenient approaches for further upgrading bio-oil. In this work, a synthetic bio-oil was prepared to overcome the limitation posed by complex nature and instability of crude bio-oil. Effects of several microemulsion parameters on the solubilization capacity of bio-oil in diesel were evaluated, including initial bio-oil/diesel volume ratio (B/D ratio), surfactant concentration (Span80), cosurfactant type (*n*-butanol, *n*-pentanol, *n*-hexanol, *n*-heptanol and *n*-octanol) and the mass ratio of cosurfactant/surfactant (C/S ratio). The optimum bio-oil/diesel volume ratio was 5 : 5. The proper concentration of Span80 was 0.36 M. *N*-octanol was certified as an ideal cosurfactant. A proper C/S ratio of 0.40 was suggested. Meanwhile, fuel properties of bio-oil/diesel microemulsion were examined, including heating value, density, kinematic viscosity, cloud point, pour point, water content, corrosivity and stability. Elemental analysis and thermogravimetric analysis of bio-oil/diesel microemulsion were conducted. Compared with the original synthetic bio-oil, the bio-oil/diesel microemulsion had more desirable fuel properties close to diesel.

14/03455 The primary forest fuel supply chain: a literature review

Wolfsmayr, U. J. and Rauch, P. *Biomass and Bioenergy*, 2014, 60, 203–221.

This paper provides a literature review of articles on the primary forest fuel supply chain which have been published in English language peer-reviewed journals from 1989 to 2011. The focus is on the key issues of the transportation of primary forest fuel to heat and/or power plants: (i) transportation modes, (ii) terminal types and (iii) forest fuel supply chain management, and provides basics on the logistically relevant characteristics of wood as feedstock such as on various feedstock assortments. The analysed supply chains include the trans-shipment, storage, handling (e.g. chipping) and transportation of primary forest fuel from the place of harvest to energy conversion plant. Due to spatial distribution, low mass density, low energy density and low bulk density, the transportation of primary forest fuel is crucial for economic efficiency as well as for reduced CO_2 emissions. As a consequence of forests accessibility, road transportation (after hauling the biomass to the forest road) is the first step of the modern primary forest fuel supply chain. For longer transportation distances, rail or waterway is preferred because of lower transportation costs per volume transported and lower CO_2 emissions. The authors highlight that some experience exists in multimodal transport, including truck, train or ship. Intermodal transport, however, has not been studied in the past and, therefore, an outlook for the research requirements is made here.

14/03456 Trade of woody biomass for electricity generation under climate mitigation policy

Favero, A. and Massetti, E. *Resource and Energy Economics*, 2014, 36, (1), 166–190.

Bio-energy with carbon capture and sequestration has the potential to be a key mitigation option because it can generate electricity and absorb emissions at the same time. However, biomass is not distributed evenly across the globe and regions with a potentially high demand might be constrained by limited domestic supply. Therefore, climate mitigation policies might create the incentive to trade biomass internationally. This paper uses scenarios generated by the integrated assessment model WITCH to study trade of woody biomass from multiple perspectives: the volume of biomass traded, its value, the impact on other power generation technologies and on the efficiency of mitigation policy. The policy scenarios consist of three representative carbon tax policies (4.8, 3.8 and 3.2 W/m^2 radiative forcing values in 2100) and a cap-and-trade scheme (3.8 W/m^2 in 2100). Results show that the incentive to trade biomass is high: at least 50% of biomass consumed globally is traded internationally. Regions trade 13–69 EJ/yr of woody biomass in 2050 and 55–81 EJ/yr in 2100. In 2100 the value of biomass traded is equal to US$0.7–7.2 trillion. Trade of woody biomass substantially increases the efficiency of the mitigation policy. In the tax scenarios, abatement increases by 120–323 Gt CO_2 over the century. In the cap-and-trade scenario biomass trade reduces the price of emission allowances by 34% in 2100 and cumulative discounted policy costs by 14%.

14/03457 Transforming duck tallow into biodiesel via noncatalytic transesterification

Kwon, E. E. *et al. Applied Energy*, 2014, 116, 20–25.

The transformation of the lipids extracted from duck tallow into biodiesel was achieved using activated alumina and CO_2 under ambient pressure (1 bar). Crude fatty acids (~98% assay) were also esterified to help us understand and validate the non-catalytic biodiesel conversion mechanisms. Its conversion efficiency was nearly 93.5($\pm$0.5)%. The transformation of crude fatty acid into biodiesel proves that this newly developed technology for the production of biodiesel combines esterification of free fatty acids and transesterification of triglycerides into a single process that has a 98.5($\pm$0.5)% conversion efficiency to biodiesel within 1 min at 350–500 °C. This paper addresses the simplest methodology for the production of biodiesel. Here it is confirmed that the main driving force of biodiesel conversion in the non-catalytic transesterification reaction is temperature rather than pressure. Non-catalytic biodiesel transformation can be achieved in the presence of a porous material via a thermochemical process in a continuous flow system. This non-catalytic biodiesel transformation was enhanced under the presence of carbon dioxide.

Geothermal energy

14/03458 A new thermal battery for powering borehole equipment: the discharge performance of Li–Mg–B alloy/$LiNO_3$–KNO_3/MnO_2 cells at high temperatures

Niu, Y. *et al. Journal of Power Sources*, 2014, 245, 537–542.

There is interest in developing a suitable battery system that can be used at temperatures of 250 °C or less to power instrumentation used in oil/gas and geothermal boreholes. The discharge performance of MnO_2 cathodes with Li–Mg–B alloy anodes is examined using the $LiNO_3$–KNO_3 eutectic electrolyte over a temperature range of 150–300 °C at current densities from 10 to 30 mA cm^{-2}. This study found that the cell can be activated at 150 °C and operate within the desired temperature range without any indication of possible hazards. However, it was observed that temperature and current density significantly affected cell capacity and voltage. Overall, the Li–Mg–B alloy/$LiNO_3$–KNO_3/MnO_2 system shows great potential for powering instrumentation used in oil/gas and geothermal boreholes.

14/03459 Combined simulation of a deep ground source heat exchanger and an office building

Huchtemann, K. and Müller, D. *Building and Environment*, 2014, 73, 97–105.

In this paper the calculation of a borehole heat exchanger, an office building and their combined dynamic simulation with simplified models was presented. Dynamic simulations are necessary to calculate the

amount of heat that can be delivered by deep geothermal heat exchangers for the heating of office buildings considering the dynamic building loads as well as the interaction with the borehole heat exchanger and the ground. The mass flow rate in the borehole heat exchanger is a crucial parameter for the efficiency of the geothermal heat generation system. Although the case studied within this paper is an office building with a deep borehole heat exchanger that was not finished as planned, it could be shown by simulations that with the current state of the borehole heat exchanger a ratio of 69% of all heating energy can be supplied by geothermal heat. This value is limited by the supply temperatures of the borehole heat exchanger and the systems of heat delivery. The value also needed to be checked against the maximum heat that can be delivered by the concrete core activation and heating panels. Measurements taken in the month of February found that only about 41% can be delivered by concrete core activation and heating panels.

14/03460 Development of borehole-jack fracturing technique for in situ stress measurement

Yokoyama, T. *et al. International Journal of Rock Mechanics and Mining Sciences*, 2014, 67, 9–19.

In order to measure crustal stresses at great depths of more than 1000 m from the ground surface, the authors have been promoting research and development of borehole-jack fracturing technique. When a borehole wall is loaded by a borehole-jack, a pair of new fractures will be induced oppositely in parallel to the borehole axis. After unloading, if the same place on the borehole wall is loaded again by the jack, the pair of fractures will be opened again. Two principal stresses and the orientation of crustal stress in the plane perpendicular to the borehole axis are determined by the re-opening pressures and the orientation of the fractures respectively. This technique is similar to a hydraulic fracturing from the viewpoint of analysis. The features of this technique are that it is possible to produce a pair of axial fractures in an arbitrary direction, possible to measure a displacement of the fracture opening, and, as a result, it is possible to determine the re-opening pressure accurately. This paper describes also documents the results of numerical analyses, laboratory experiments, and field tests.

14/03461 Drilling performance, injectivity and productivity of geothermal wells

Sveinbjornsson, B. M. and Thorhallsson, S. *Geothermics*, 2014, 50, 76–84.

Drilling performance of 77 high-temperature production and reinjection wells in the Hengill area in Iceland was analysed. The results demonstrate that the perceived high risk of drilling in a proven field is less than commonly thought. No difference was found in the time required to drill holes of $13\frac{3}{8}''$ or $9\frac{5}{8}''$ production casing but the wider wells delivered 30–40% more steam. The average power output per drilled well amounts to 5.9 MW_e but 7.5 per productive well. To predict steam mass flow on the basis of the injectivity index one must consider reservoir conditions and enthalpy of the expected inflow into wells.

14/03462 Experimental study on interaction between soil and ground heat exchange pipe at low temperature

Wang, Y. *et al. Applied Thermal Engineering*, 2013, 60, (1–2), 137–144.

In the application of ground source heat pumps in cold regions, soil–pipe interaction due to frost heave can lead to many problems influencing the system efficiency. The aim of this experimental study is to investigate the characteristics of soil–pipe interaction and test the feasibility of reducing the pipe deformation by increasing the grain size of soil in backfill. In this study, two types of soils with different grain sizes are used, the movement of freezing front, the pipe deformation and the freezing soil pressure on pipe are analysed. The results indicate that the U-pipe can result in an asymmetrical soil freezing area around it, the pipe's cross-section changes to be more and more elliptical, the soil pressure on pipe increases. An obvious reduction in the pipe deformation and the soil pressure on pipe can be shown in the soil with larger grain size, and the application of suitable large-grain soils in backfill is helpful to reduce the pipe deformation.

14/03463 Exploration and monitoring geothermal activity using Landsat ETM+ images: a case study at Aso volcanic area in Japan

Mia, M. B. *et al. Journal of Volcanology and Geothermal Research*, 2014, 275, 14–21.

Thermal activity monitoring in and around active volcanic areas using remote sensing is an essential part of volcanology nowadays. Three identical approaches were used for thermal activity exploration at Aso volcanic area in Japan using Landsat ETM+ images. First, the conventional methods for hydrothermal alteration mapping were applied to find the most active thermal region after exploring geothermal indicator minerals. Second, some thermally highly anomalous regions were found around Nakadake crater using land surface temperature estimation. Then, the Stefan–Boltzmann equation was used for estimating and also monitoring radiative heat flux (RHF) from the most active region of about 8 km^2 in and around Nakadake crater in the central part of the Aso volcano. To fulfil the required parameter in the Stefan–Boltzmann equation for radiative heat flux, the normalized differential vegetation index (NDVI) method was used for spectral emissivity, and the mono-window algorithm was used for land surface temperature of this study area. The NDVI value was used to divide land-cover in the study area into four types: water, bare ground, mixed and vegetated land. The bare land was found within the most active region. Vegetation coverage area showed an inverse relationship with total RHF in this study as health of thermally stressed vegetation supports this relationship. The spatial distribution of spectral emissivity ranged from 0.94 to 0.99 in this study. Land surface temperature was estimated using a mono-window algorithm and was highest LST in 2008 and lowest in 2011. The results of RHF showed that the highest pixel RHF was found to be about 296 W/m^2 in 2008. Total RHF was obtained of about 607 MW in 2002 and the lowest was about 354 MW in 2008. The RHF anomaly area was found the highest in 2002 and was lowest in 2011. The highest total heat discharge rate (HDR) obtained about 3918 MW in 2002 and lowest total HDR about 2289 MW in 2008 from this study area. But in the case of Nakadake crater alone, the higher thermal activity was observed in 2008 and was less in 2004. The study showed that Landsat thermal infrared is the best option for thermal activity exploration and monitoring at Aso volcano as well as in any active volcano region considering high efficiency and low cost.

14/03464 Heat dissipation effect on a borehole heat exchanger coupled with a heat pump

Darkwa, J. *et al. Applied Thermal Engineering*, 2013, 60, (1–2), 234–241.

Thermal performance evaluation of a ground-coupled heat exchanger has been undertaken to assess the extent of heat dissipation into the ground and its long-term effect on the cooling performance of a heat pump system. Simulation results were compared with operational data over a 3-year period and found to be in good agreement. However, the annual average energy being dissipated into the borehole was found to be about 4.5 times more than the amount being extracted thus raising concern about long-term effectiveness of the borehole as a heat sink. Even though there was a slight decline in the energy dissipation rate during the third year, the result does not provide adequate evidence to support creeping soil degradation process in the borehole over such a relatively short period. Since the performance of each ground-coupled heat exchanger appears to be influenced by its location, more research is needed to acquire better and wider understanding of the effect of heat dissipation and soil degradation processes in borehole systems.

14/03465 Optimization of operating parameters of ground source heat pump system for space heating and cooling by Taguchi method and utility concept

Sivasakthivel, T. *et al. Applied Energy*, 2014, 116, 76–85.

Use of ground source energy for space heating applications through ground source heat pumps (GSHPs) has been established as an efficient thermodynamic process. The electricity input to the GSHP can be reduced by increasing the coefficient of performance (COP) of the system. However, the COP of a GSHP system will be different for heating and cooling mode operations. Hence, in order to reduce the electricity input to the GSHP, an optimum value of COP has to be determined when GSHP is operated in both heating and cooling modes. In the present research, a methodology is proposed to optimize the operating parameters of a GSHP system which will operate on both heating and cooling modes. Condenser inlet temperature, condenser outlet temperature, dryness fraction at evaporator inlet and evaporator outlet temperature are considered as the influencing parameters of the heat pump. Optimization of these parameters for only heating or only cooling mode operation is achieved by employing Taguchi method for three level variations of the above parameters using an L_9 (3^4) orthogonal array. A computer program in FORTRAN has been developed to carry out the computations and the results have been analysed for the optimum conditions using signal-to-noise ratio and analysis of variance method. Based on this analysis, the maximum COP for only heating and only cooling operation are obtained as 4.25 and 3.32, respectively. By making use of the utility concept both the higher values of COP obtained for heating and cooling modes are optimized to get a single optimum COP for heating and cooling modes. A single optimum COP value of 3.92 has been obtained for both space heating and cooling operations.

14/03466 Potential use of geothermal energy sources for the production of lithium-ion batteries

Saevarsdottir, G. *et al. Renewable Energy*, 2014, 61, 17–22.

The lithium-ion battery is one of the most promising technologies for energy storage in many recent and emerging applications. However, the cost of lithium-ion batteries limits their penetration in the public market. Energy input is a significant cost driver for lithium batteries due to both the electrical and thermal energy required in the production process. The drying process requires 45–57% of the energy consumption of the production process according to a model presented

in this paper. The model is used as a base for quantifying the energy and temperatures at each step, as replacing electric energy with thermal energy is considered. In Iceland, it is possible to use geothermal steam as a thermal resource in the drying process. The most feasible type of dryer and heating method for lithium batteries would be a tray dryer (batch) using a conduction heating method under vacuum operation. Replacing conventional heat sources with heat from geothermal steam in Iceland, the energy cost can be lowered to US$0.008/Ah from US$0.13/Ah based on average European energy prices. The energy expenditure after 15 years operation could be close to 2% of total expenditure using this renewable resource, down from 12% to 15% in other European countries. According to the profitability model, the internal rate of return of this project will increase from 11% to 23% by replacing the energy source. The impact on carbon emissions amounts to 393.4–215.1 g/Ah lower releases of CO_2 per year, which is only 2–5% of carbon emissions related to battery production using traditional energy sources.

14/03467 Spatial distribution of hydrogen sulfide from two geothermal power plants in complex terrain

Olafsdottir, S. *et al. Atmospheric Environment*, 2014, 82, 60–70.

Concerns have arisen about the health impact and odour annoyance of hydrogen sulfide (H_2S) emissions associated with geothermal power production. Measurements have been made at stationary measuring stations in inhabited areas but little is known about the spatial behaviour of the H_2S plumes. This study presents field measurements of the spatial distribution of the ground concentration of H_2S within a 30 km radius of two geothermal power plants during 20 distinct events spanning one year. The results showed that high H_2S concentration was correlated with high air stability, low wind speed and absence of precipitation. The odour threshold ($11\,\mu g\,m^{-3}$) was exceeded in all events. The instantaneous measurements exceeded the 24-h average national health limit ($50\,\mu g\,m^{-3}$) up to 26 km from the power plants. The shape of the measured plumes at the same location was similar between events, indicating repeated patterns in plume distribution. Convergence of plumes was observed due to spatial variability in wind direction. Plumes were found to follow mountain passes and accumulate alongside a mountain range. AERMOD modelling demonstrated that narrower plumes with higher concentration can be expected for smoother terrain, such as lakes, consistent with measurements.

14/03468 Status and development of hybrid energy systems from hybrid ground source heat pump in China and other countries

Qi, Z. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 37–51.

Hybrid energy systems (HES) facilitate the efficient utilization of renewable resources and sustainable energy, and they are expected to be more prevalent in the future. With ground source heat pump (GSHP) as the main body and core technology, the hybrid ground source heat pump (HGSHP) system has been used frequently in recent years and its integration and synthesis skills face higher requirements. The worldwide hybrid system has usually been composed of types of energy source devices, such as solar collector, boiler (coal, gas, oil), electric heater, waste energy device, cooling tower, cooler and thermal storage system with natural cold and hot. They lead to complicated and unsteady processes and various hybrid energy systems. In China, the applications of these systems are growing year by year, but new technology breakthroughs are difficult. This paper reviews the progress of GSHP combined with HES all over the world, and surveyed the development of HGSHP in China. Meanwhile, the basic proposals for development in the future are presented to make up the gap in the field of HES and HGSHP. These problems will strengthen theoretical and practical understanding of HES and facilitate more extensive application of HGSHP in China.

14/03469 Texas' geothermal resource base: a raster-integration method for estimating in-place geothermal-energy resources using ArcGIS

Zafar, S. D. and Cutright, B. L. *Geothermics*, 2014, 50, 148–154.

The large sedimentary basins of Texas, USA have been and are currently the subject of intensive petroleum exploration and production. The Gulf Coast, east Texas, the Anadarko Basin and west Texas have all produced significant volumes of both oil and gas. Many of the fields and reservoirs within these basins are now mature or reaching the end of their productive lives and present an opportunity for these deep formations to be transitioned from petroleum production to geothermal-energy production using the existing infrastructure and the legacy of geologic information created by the oil and gas industry. The Gulf Coast and the Anadarko Basin have previously been analysed for thermal energy in place, although formations in east and west Texas have not. A problem lies in the fact that previous studies may have overestimated thermal energy by employing a more simplistic method, in which a basin is split into one or more uniform-temperature blocks for which thermal energy in place is calculated. This is overcome in the present study by using ArcGIS to create a maximum extractable depth raster for both maximum well depth and maximum extractable depth in regions of Texas. The thermal energy in place is then derived through integration of the geothermal gradient raster over the block volume defined by the maximum depth raster to estimate thermal energy in place. A reference temperature of 93 °C (200 °F) is used. The results of this methodology indicate that 1.66×10^{23} J (2.71×10^{13} bbl oil equivalent) reside in place in Texas that is accessible using existing wells. Regionally the Gulf Coast contains 3.20×10^{22} J (5.24×10^{12} bbl oil equivalent), east Texas contains 4.04×10^{22} J (6.60×10^{12} bbl oil equivalent), west Texas contains 1.42×10^{22} J (2.32×10^{12} bbl oil equivalent), and north Texas contains 4.20×10^{21} J (6.87×10^{11} bbl oil equivalent).

14/03470 The Domuyo volcanic system: an enormous geothermal resource in Argentine Patagonia

Chiodini, G. *et al. Journal of Volcanology and Geothermal Research*, 2014, 274, 71–77.

A geochemical survey of the main thermal waters discharging in the south-western part of the Domuyo volcanic complex in Argentina, where the latest volcanic activity dates to 0.11 Ma, has highlighted the extraordinarily high heat loss from this remote site in Patagonia. The thermal water discharges are mostly Na-Cl in composition and have total dissolved solids values up to $3.78\,g\,L^{-1}$ (El Humazo). A simple hydrogeochemical approach shows that $1100–1300\,kg\,s^{-1}$ of boiling waters, which have been affected by shallow steam separation, flow into the main drainage of the area (Rio Varvarco). A dramatic increase of the most conservative species such as Na, Cl and Li from the Rio Varvarco from upstream to downstream was observed and related solely to the contribution of hydrothermal fluids. The equilibrium temperatures of the discharging thermal fluids, calculated on the basis of the Na–K–Mg geothermometer, are between 190 and 230 °C. For a liquid originally at 220 °C (enthalpy = $944\,J\,g^{-1}$), the thermal energy release can be estimated as high as 1.1 ± 0.2 GW, a value that is much higher than the natural release of heat in other important geothermal fields worldwide, e.g. Mutnovsky (Russia), Wairakei (New Zealand) and Lassen Peak (USA). This value is the second highest measured advective heat flux from any hydrothermal system on Earth after Yellowstone.

14/03471 Transient heat transfer in a U-tube borehole heat exchanger

Beier, R. A. *Applied Thermal Engineering*, 2014, 62, (1), 256–266.

A transient heat transfer model has been developed for a thermal response test (TRT) on a vertical borehole with a U-tube. Vertical borehole heat exchangers are frequently coupled to ground source heat pumps, which heat and cool buildings. The model provides an analytical solution for the vertical temperature profiles of the circulating fluid through the U-tube, and the temperature distribution in the ground. The model is verified with data sets from a laboratory sandbox and field TRTs, as well as a previously reported numerical solution. Unlike previous analytical models, the vertical profiles for the circulating fluid are generated by the model without any assumption of their functional form. The model fits the transient temperature curves for the measured inlet and outlet circulating fluid over the entire test period. By generating vertical temperature profiles of the circulating fluid, the model is able to estimate borehole resistance without relying on the mean temperature approximation. For one of the field data sets, the model indicates the borehole resistance is 18% less than the value estimated by methods using the mean temperature approximation.

Solar energy

14/03472 Augmentation of natural convection heat transfer in triangular shape solar collector by utilizing water based nanofluids having a corrugated bottom wall

Rahman, M. M. *et al. International Communications in Heat and Mass Transfer*, 2014, 50, 117–127.

Nanofluids have been introduced for the enhancement in the heat transfer phenomena in recent years. In this paper, a corrugated bottom triangular solar collector has been studied introducing water-based nanofluids inside the enclosure. The corrugated bottom is kept at a constant high temperature whereas the side walls of the triangular enclosure are kept at a low temperature. Three types of nanoparticles are taken into consideration: Cu, Al_2O_3 and TiO_2. The effect of solid volume fraction (ϕ) of the nanoparticle of nanofluid has been studied numerically by Galerkin weighted residual method of finite element for a wide range of Grashof number (Gr) 10^4–10^6. Calculations are carried out for $\phi = 0$, 0.05, 0.08, and 0.1 and dimensionless time, $\tau = 0.1$, 0.5 and 1.0. For the specified conditions, streamlines and isotherm

contours are obtained and detailed results of the interaction between different parameters are studied using overall Nusselt number. It has been found that both *Gr* and solid volume fraction have significant influence on streamlines and isotherms in the enclosure. It is also found that heat transfer increased by 24.28% from the heated surface as volume fraction ϕ increases from 0% to 10% at $Gr = 10^6$ and $\tau = 1$ for copper water nanofluid.

14/03473 Biophotovoltaics: natural pigments in dye-sensitized solar cells

Hug, H. *et al. Applied Energy*, 2014, 115, 216–225.

Dye-sensitized solar cells (DSSCs) which are also called Graetzel cells are a novel type of solar cells. Their advantages are mainly low cost production, low energy payback time, flexibility, performance also at diffuse light and multicolour options. DSSCs become more and more interesting since a huge variety of dyes including also natural dyes can be used as light harvesting elements which provide the charge carriers. A wide band gap semiconductor like TiO_2 is used for charge separation and transport. Such a DSSC contains similarities to the photosynthetic apparatus. Therefore, this study summarizes current available knowledge on natural dyes that have been used in DSSCs which should provide reasonable light harvesting efficiency, sustainability, low cost and easy waste management. Promising natural compounds are carotenoids, polyphenols and chlorophylls.

14/03474 Description and characterization of an adjustable flux solar simulator for solar thermal, thermochemical and photovoltaic applications

Sarwar, J. *et al. Solar Energy*, 2014, 100, 179–194.

A high flux solar simulator for indoor performance assessment of systems in solar thermal, thermochemical and high concentration photovoltaic research offers repeatability under controlled climate conditions. This paper presents a new high flux solar simulator where a 7 kW xenon short arc lamp coupled with a truncated ellipsoid reflector is used as the light source. The flux mapping method is used to evaluate performance of this high flux solar simulator on the basis of flux distribution, temporal instability, spatial non-uniformity, peak flux, conversion efficiency and power intercepted on a circular target placed at the focal plane. The input current of the simulator is adjusted in the range of 113–153 A to quantify the maximum and minimum peak flux output per power settings of the solar simulator, which yield different flux distribution at different power level. A theoretical comparative analysis of manufacturer's sensor scaling factor of the circular foil heat flux gage with literature is performed and an optimum scaling factor of 491.46 kW m^{-2}/mV is selected to relate measured incident flux with a charge-coupled device camera's greyscale value of acquired image. It was observed that at an input current of 153 A, the simulator delivers a peak flux of 3583 kW m^{-2}, temporal instability of radiative output less than 3%, and cumulative beam power of 1.642 kW at a circular target radius of 110 mm placed at the focal plane. A conversion efficiency at 153 A and 110 mm radius was determined to be 47%. For a photovoltaic cell size of 1.5 mm radius, the solar simulator provides an average incident flux in the range of 1200–3000 suns with class 'A' temporal instability and class 'B' spatial non-uniformity. The simulator is capable of adjusting peak flux in the range of 2074–3583 kW m^{-2} and can produce a theoretical black body stagnation temperature of 1857 K.

14/03475 Economic implications of thermal energy storage for concentrated solar thermal power

Wagner, S. J. and Rubin, E. S. *Renewable Energy*, 2014, 61, 81–95.

Solar energy is an attractive renewable energy source because the sun's energy is plentiful and carbon-free. However, solar energy is intermittent and not suitable for base load electricity generation without an energy backup system. Concentrated solar power (CSP) is unique among other renewable energy options because it can approach base load generation with molten salt thermal energy storage (TES). This paper describes the development of an engineering economic model that directly compares the performance, cost, and profit of a 110-MW parabolic trough (PT) CSP plant operating with a TES system, natural gas-fired backup system, and no backup system. Model results are presented for 0–12 h backup capacities with and without current US subsidies. TES increased the annual capacity factor from around 30% with no backup to up to 55% with 12 h of storage when the solar field area was selected to provide the lowest levelized cost of energy (LCOE). Using TES instead of a natural gas-fired heat transfer fluid heater (NG) increased total plant capital costs but decreased annual operation and maintenance costs. These three effects led to an increase in the LCOE for PT plants with TES and NG backup compared with no backup. LCOE increased with increasing backup capacity for plants with TES and NG backup. For small backup capacities (1–4 h), plants with TES had slightly lower LCOE values than plants with NG backup. For larger backup capacities (5–12 h), plants with TES had slightly higher LCOE values than plants with NG backup. At these costs, current US federal tax incentives were not sufficient to make PT profitable in a market with variable electricity pricing. Current US incentives combined with a fixed electricity price of $200/MWh made PT plants with larger backup capacities more profitable than PT plants with no backup or with smaller backup capacities. In the absence of incentives, a carbon price of $100–160/tonne CO_{2eq} would be required for these PT plants to compete with new coal-fired power plants in the USA. If the long-term goal is to increase renewable base load electricity generation, additional incentives are needed to encourage new CSP plants to use thermal energy storage in the USA.

14/03476 Enhanced operation of stand-alone 'photovoltaic-diesel generator-battery' system

Malla, S. G. and Bhende, C. N. *Electric Power Systems Research*, 2014, 107, 250–257.

In this paper, enhanced operation of a stand-alone photovoltaic (PV)–diesel generator (DG)–battery system is presented. Fluctuations in output power due to weather conditions and partial shading are the common problems in PV system. Therefore, Takagi–Sugeno (TS) fuzzy-based DC voltage control is proposed to extract maximum power under the conditions of fluctuating weather and partial shading. Under light load conditions, deloaded operation of PV from its maximum power point (MPP) is incorporated to maintain real power balance of system. The novel inverter control helps in maintaining balanced point-of-common-coupling voltages and balanced DG currents under the condition of unbalanced load. Making DG currents balanced reduces the oscillations in generator torque which increases the fatigue life of the generator shaft. Moreover, with inverter control it is found that the inverter should supply the reactive power required by the load. Hence, DG needs not need to supply reactive power which will reduce the diesel consumption. Detailed Matlab results are presented considering different case studies and a few real-time digital simulator results are also presented in support of the theory.

14/03477 Environmental impacts of large-scale grid-connected ground-mounted PV installations

Beylot, A. *et al. Renewable Energy*, 2014, 61, 2–6.

This study characterizes the environmental performances of large-scale ground-mounted photovoltaic (PV) installations by considering a life cycle approach. The methodology is based on the application of the existing international standards of life cycle assessment (LCA). Four scenarios are compared, considering fixed-mounting structures with (1) primary aluminium supports or (2) wood supports, and mobile structures with (3) single-axis trackers or (4) dual-axis trackers. Life cycle inventories are based on manufacturers' data combined with additional calculations and assumptions. Fixed-mounting installations with primary aluminium supports show the largest environmental impact potential with respect to human health, climate change and energy consumption. The climate change impact potential ranges between 37.5 and 53.5 g CO_2 eq/kWh depending on the scenario, assuming 1700 kWh/m^2 yr of irradiation on an inclined plane (30°), and multi-crystalline silicon modules with 14% of energy production performance. Mobile PV installations with dual-axis trackers show the largest impact potential on ecosystem quality, with a difference of greater than a factor of two with other considered installations. Supports mass and composition, power density (in MWp/acre of land) and energy production performances appear as key design parameters with respect to large-scale ground-mounted PV installations environmental performances, in addition to modules manufacturing process energy inputs.

14/03478 Environmental impacts of utility-scale solar energy

Hernandez, R. R. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 766–779.

Renewable energy is a promising alternative to fossil fuels, but its development can require a complex set of environmental tradeoffs. A recent increase in solar energy systems, especially large, centralized installations, underscores the urgency of understanding their environmental interactions. Synthesizing literature across numerous disciplines, the authors review direct and indirect environmental impacts – both beneficial and adverse – of utility-scale solar energy (USSE) development, including impacts on biodiversity, land use and land-cover change, soils, water resources and human health. Additionally, feedback between USSE infrastructure and land-atmosphere interactions and the potential for USSE systems to mitigate climate change is reviewed. Several characteristics and development strategies of USSE systems have low environmental impacts relative to other energy systems, including other renewables. The authors show opportunities to increase USSE environmental co-benefits, the permitting and regulatory constraints and opportunities of USSE, and highlight future research directions to better understand the nexus between USSE and the environment. Increasing the environmental compatibility of USSE systems will maximize the efficacy of this key renewable energy source in mitigating climatic and global environmental change.

14/03479 Evaluation of the environmental performance of sc-Si and mc-Si PV systems in Korea

Kim, B.-j. *et al. Solar Energy*, 2014, 99, 100–114.

In this study, environmental issues associated with silicon-based photovoltaic (PV) systems in Korea are investigated using life cycle assessment (LCA). The target PV systems are single-crystalline silicon (sc-Si) and multi-crystalline silicon (mc-Si) modules with a power conditioning system and balance of system. In order to identify the environmental benefits and key environmental issues associated with the deployment of these systems, the global warming potential (GWP), fossil-fuel consumption (FFC), CO_2 payback time (CO_2PBT), and energy payback time of the target PV systems throughout their life cycles are analysed. The LCA results show that sc-Si and mc-Si PV systems are superior to the current grid mix in Korea with respect to GWP and FFC. For the current conversion efficiency, the mc-Si PV system has lower values of GWP and FFC. With the predicted improvements in conversion efficiency, the GWP results associated with the construction phase of sc-Si and mc-Si PV system will be offset by electricity generated in 1.66 and 1.53 years, since then 1470 and 1477 tonne CO_2 equiv. of greenhouse gases are reduced during their lifetimes, respectively. In addition, the energy inputs during sc-Si and mc-Si PV system's construction phase will be offset in 3.11 and 2.97 years, since by then 10.15 and 10.20 TJ of net energy benefit will have been obtained, respectively. Considering the planned deployment of PV systems in Korea and the expected improvements in PV module efficiencies, the net CO_2 reduction and net energy benefit between 2010 and 2030 were calculated. If 0.45% of the Korean grid mix was substituted with mc-Si PV systems, and a conversion efficiency of 20.30% were attained, the net CO_2 reduction would be a 69.8 Mtonne CO_2 equiv. The supply plan is achieved using sc-Si PV systems, which achieve a conversion efficiency of 27.60%; the net energy benefit would be 410.6 TJ, which is equivalent to 4.3% of the total primary energy supply in 2009. It is shown that sc-Si and mc-Si PV systems would be suitable solutions to reduce energy consumption and CO_2 emissions if they replaced non-renewable energy sources in Korea.

14/03480 Grid-connected photovoltaic system in Malaysia: a review on voltage issues

Wong, J. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 535–545.

Photovoltaic (PV) systems are the most promising renewable energy source in Malaysia due to its abundant solar irradiation. The Malaysian government has launched various renewable energy programmes to encourage the use of PV systems. Most of the PV systems are single-phase and the installation is customer driven. Therefore, the growth of PV systems in low-voltage (LV) distribution networks has the potential to raise several technical issues including voltage rise and voltage unbalance. Furthermore, Malaysia is a warm country and surrounded by the sea. The vaporization of sea water together with seasonal winds results in a large amount of passing cloud, making this country, possibly, the cloudiest region in the world, therefore solar irradiation is highly scattered and fluctuating. The power output from PV is highly intermittent, hence producing an enormous amount of voltage fluctuations and flickers on the LV distribution networks. All these voltage issues have to be studied experimentally and addressed thoroughly at the early stage before the amount of PV on the network becomes substantial. Therefore, a 7.2 kW grid connected PV system on a radial LV distribution network has been set up to study the voltage issues at the point of common coupling. The power outputs of the PV system are characterized and compared with that of other countries. The probability density of voltage rise and voltage unbalanced factors are derived from the measurement data. Short- and long-term voltage flicker indexes are calculated to evaluate the severity of the flicker emission. These results are valuable to policy makers, electricity regulatory bodies, utility companies, customers and PV manufacturers because they can change the policy on the renewable energy and the regulatory framework.

14/03481 Hybrid photovoltaic generation system with novel islanding detection method

Shen, J.-M. *et al. Electric Power Systems Research*, 2014, 106, 101–108.

This paper proposes an islanding detection method for a hybrid photovoltaic generation system (HPGS). This HPGS is controlled using an improved voltage-mode control method in both the grid-connected and the stand-alone conditions to unify and simplify the control circuit. The inverter of this HPGS is multi-functional, so it can perform the functions of active power filter, charging/discharging a battery set, uninterruptible power supply, and injecting power into the grid of distribution power system. The proposed islanding detection method is incorporated into the controller of the inverter. The advantage of islanding detection method is the time required to add a disturbance for detecting the islanding operation is very short. A prototype is developed and tested to verify the performance of the proposed HPGS. The experimental results verify that the proposed islanding detection method can effectively detect the islanding operation, so this HPGS achieves the expected performance.

14/03482 Latent heat augmentation of thermocline energy storage for concentrating solar power – a system-level assessment

Flueckiger, S. M. and Garimella, S. V. *Applied Energy*, 2014, 116, 278–287.

Molten-salt thermocline tanks are a low-cost energy storage option for concentrating solar power plants. Despite the potential economic advantage, the capacity of thermocline tanks to store sufficient amounts of high-temperature heat is limited by the low energy density of the constituent sensible-heat storage media. A promising design modification replaces conventional rock filler inside the tank with an encapsulated phase-change material (PCM), contributing a latent heat storage mechanism to increase the overall energy density. The current study presents a new finite-volume approach to simulate mass and energy transport inside a latent heat thermocline tank at low computational cost. This storage model is then integrated into a system-level model of a molten-salt power tower plant to inform tank operation with respect to realistic solar collection and power production. With this system model, PCMs with different melting temperatures and heats of fusion are evaluated for their viability in latent heat storage for solar plants. Thermocline tanks filled with a single PCM do not yield a substantial increase in annual storage or plant output over a conventional rock-filled tank of equal size. As the melting temperature and heat of fusion are increased, the ability of the PCM to support steam generation improves but the corresponding ability of the thermocline tank to utilize this available latent heat decreases. This trend results from an inherent deconstruction of the heat-exchange region inside the tank between sensible and latent heat transfer, preventing effective use of the added phase change for daily plant operations. This problem can be circumvented with a cascaded filler structure composed of multiple PCMs with their melting temperatures tuned along the tank height. However, storage benefits with these cascaded tank structures are shown to be highly sensitive to the proper selection of the PCM melting points relative to the thermocline tank operating temperatures.

14/03483 On the effects of windbreaks on the aerodynamic loads over parabolic solar troughs

García, E. T. *et al. Applied Energy*, 2014, 115, 293–300.

Parabolic reflectors, also known as parabolic troughs, are widely used in solar thermal power plants. This kind of power plant is usually located in desert climates, where the combined action of wind and dust can be of paramount importance. In some cases it becomes necessary to protect these devices from the joined wind and sand action, which is normally accomplished through solid windbreaks. In this paper, the results of a wind tunnel test campaign, of a scale parabolic trough row having different windward windbreaks, are reported. The windbreaks considered here consist of a solid wall with an upper porous fence. Different geometrical configurations, varying the solid wall height and the separation between the parabolic trough row and the windbreak have been considered. From the measured time series, both the mean and peak values of the aerodynamic loads were determined. As it would be expected, mean aerodynamic drag, as well as peak values, decrease as the distance between the windbreak and the parabolic increases, and after a threshold value, such drag loads increase with the distance.

14/03484 Optimization of the optical particle properties for a high temperature solar particle receiver

Ordóñez, F. *et al. Solar Energy*, 2014, 99, 299–311.

A non-homogeneous slab of particle dispersion composed of two-layers at high temperature, submitted to a concentrated and collimated solar radiation flux with a reflective receiver back wall is considered as a model of a solar particle receiver. The radiative transfer equation is solved using a two-stream method and an appropriate hybrid modified Eddington-delta function approximation. The single particle optical properties are modelled using the Lorenz–Mie theory, the single particle phase function is approximated by the Henyey–Greenstein phase function. A particle swarm optimization algorithm is used to optimize the particle radius ($0.1\,\mu m \leq r \leq 100\,\mu m$), the volume fraction ($1\times10^{-7} \leq f_v \leq 1\times10^{-4}$) and the refractive index ($2.0 \leq n \leq 4.5$ and $0.0001 \leq k \leq 25$) of an ideal theoretical material to use in a solar particle receiver. Single- and two-layer receivers with known temperature profiles were optimized to maximize the receiver efficiencies. Spectral selective behaviour of the optimized refractive index is discussed with the influence of particle radii and volume fractions. The theoretical ideal optical properties found for the particles have given the maximum efficiency reachable by the studied receivers and have shown that an optimized single-layer receiver will perform as well as a two-layer receiver.

14/03485 Performance characteristics of a low concentrated photovoltaic–thermoelectric hybrid power generation device

Liao, T. *et al. International Journal of Thermal Sciences*, 2014, 77, 158–164.

A theoretical model of a hybrid power generation device consisting of a low concentrated photovoltaic (CPV) module and a thermoelectric generator (TEG) is established in this paper. The expressions for the efficiency and power output of the hybrid device are derived and the performance characteristics of the device are presented and discussed in detail, based on non-equilibrium thermodynamics theory and law of conservation of energy. The maximum power output of the hybrid device is calculated numerically and the load electric resistances of the CPV and TEG are determined optimally. The influences of several important factors such as the thermal conductance between the CPV and the TEG, the current of the CPV, the solar irradiation, the concentrating ratio and the figure of merit of the TEG on the power output of the hybrid device are analysed. It is found that there exist certain optimum criteria for some important parameters. The results obtained here may provide some useful criteria for the optimal design and performance improvements of a typical irreversible CPV–TEG hybrid device and other similar hybrid system as well.

14/03486 Photovoltaic optimizer boost converters: temperature influence and electro-thermal design

Graditi, G. *et al. Applied Energy*, 2014, 115, 140–150.

Photovoltaic (PV) systems can operate in the presence of non-uniform working conditions caused by continuously changing temperature and irradiance values and mismatching and shadowing phenomena. The more the PV system works in these conditions, the more its energy performances are negatively affected. Distributed maximum power point tracking (DMPPT) converters are now increasingly used to overcome this problem and to improve PV applications' efficiency. A DMPPT system consists in a DC–DC converter equipped with a suitable controller dedicated to the maximum power point tracking of a single PV module. It is arranged either inside the junction-box or in a separate box close to the PV generator. Many power optimizers are now commercially available. In spite of different adopted DC–DC converter topologies, the common requirements of DMPPT systems are high efficiency and reliability values. In this investigation, an electro-thermal design methodology is proposed and a reliability study by means of the Military Handbook 217F is carried out. The proposed method is applied to diode rectification (DR) boost and synchronous (SR) boost designs. To comprehensively evaluate the results, efficiency, cost and reliability performances are evaluated. Pareto fronts in terms of European efficiency and cost are identified for the SR and DR cases. A SR converter characterized by a European efficiency of 97.1% and a DR boost characterized by a European efficiency of 95.5% are chosen. Their cost is comparable and equal about to $11. Their reliability performances are evaluated by means of the Military Handbook 217F Notice 2. The analysis shows that, for the same device cost, the SR converter is the best solution if efficiency is the most critical aspect. DR boost is the optimum solution if reliability is the most important requirement. To correctly select the most suitable optimizer, a characterization in terms of efficiency, cost and reliability is carried out. In detail, the SR optimizer is characterized by lower losses and higher efficiency than the DR one. On the other hand, the DR boost results more reliable than the SR converter. So the optimum solution has to be chosen on the base of the most critical requirement. The developed method can represent a useful tool to design DMPPT optimizers able to assure high-level performances in terms of economic and technical aspects. This method can be applied to many commercially available PV generators and, without loss of generality, it can be used with different DC–DC converter topologies.

14/03487 Solar energy captured by a curved collector designed for architectural integration

Rodríguez-Sánchez, D. *et al. Applied Energy*, 2014, 116, 66–75.

This study presents a prototype for a new type of solar thermal collector designed for architectural integration. In this proposal, the conventional geometry of a flat solar thermal collector is changed to a curved geometry, to improve its visual impact when mounted on a building facade or roof. The mathematical equations for the beam and diffuse solar radiation received by a collector with this geometry are developed for two different orientations, horizontal and vertical. The performance of this curved prototype, in terms of solar radiation received, is compared with a conventional tilted-surface collector for different orientations in Madrid, Spain. The comparison is made for typical clear-sky days in winter and summer as well as for an entire year. The results demonstrate that the curved collector only receives between 12% and 25% less radiation than the conventional tilted-surface collectors when oriented horizontally, depending on the azimuth of the curved surface, although these percentages are reduced to approximately 50% when the collector is oriented vertically.

14/03488 Spatial viability analysis of grid-connected photovoltaic power systems for Turkey

Caglayan, N. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 56, 270–278.

This paper investigates viability of 0.2, 0.5, 1, 3, 5 and 10 MW grid-connected photovoltaic (PV) power plants using 22-year data for 135 locations across Turkey and RETScreen model to predict energy production. Mean annual global solar radiation, sunshine duration and ambient air temperature were spatially interpolated over Turkey based on universal kriging method. The technical renewable energy potential of grid-connected solar PV in Turkey estimated for a 0.2–10 MW power plant, on average, ranged from 0.31 to 15.56 GW h m^{-2} yr^{-1} for a fixed system, and from 0.41 to 20.81 GW h m^{-2} yr^{-1} for a dual-axis tracker in direct alignment with the sun. The use of the proposed PV grid-connected power plants was found to provide the highest energy production in Osmaniye, Dalaman and Koycegiz and the lowest energy production in Tosya, Gumushane and Artvin.

14/03489 Strategic policy to select suitable intermediaries for innovation to promote PV solar energy industry in China

Chen, H. H. *et al. Applied Energy*, 2014, 115, 429–437.

Ever since its commitment to the Copenhagen Accord of 2009 to lower its carbon emissions by 2020 to a level that will be 40% below those of 2005, China has been aiming to develop its photovoltaic (PV) solar energy industry. Because knowledge is a critical factor for obtaining a sustainable competitive advantage in a knowledge-intensive industry, it is essential to build up an interactive learning and communicating platform as a facilitator to absorb, distribute and create knowledge within a firm and among its suppliers and customers. However, relevant literature has, hitherto, never discussed such an intermediary platform for innovation. Therefore, this paper proposes some conceptual assumptions to solve this problem. After a practical investigation, this paper seeks to find suitable intermediaries for innovation at different levels of the PV solar energy supply chain in China. From a managerial point of view, the most suitable intermediaries for innovation should be viewed from a hierarchical structure. In the first tier of intermediaries for innovation, systemic instruments for the support of innovation at a higher system level, located at the conceptual stage in the midstream supply chain, should provide the strongest guidance of strategic policies and facilitate the strongest transfer of core technologies, human resources and information flows within a firm or among suppliers and customers. In the second tier of intermediaries for innovation, brokerage organizations that forge peer networks, located at the development stage of the upstream supply chain, at the development stage of the midstream supply chain, and at the conceptual stage of the downstream supply chain, should facilitate the highest transfer of core technologies, human resources and information flows from person to person, project to project and from firm to firm. In the third tier of intermediaries for innovation, innovation consultants aimed at collectives of entrepreneurs, located at the production stage of upstream, midstream and downstream supply chain, should stress specific knowledge transference within engineering functions in the context of production supply chains.

14/03490 Sustainable feasibility of solar photovoltaic powered street lighting systems

Liu, G. *International Journal of Electrical Power & Energy Systems*, 2014, 56, 168–174.

In the past few years, due to increasing fuel prices and gas emissions, renewable energy technologies have been suggested as the power source for infrastructures. The interest in solar photovoltaic (PV)-assisted street lighting systems stems from the fact that they are sustainable and environmentally friendly compared to conventionally powered systems. The present paper investigates and compares the economic feasibility of two types of systems: islanded and grid-connected system, for the street lighting systems in Hunan Province, China. Based on two options of solar panel materials, a simulation model of the system is developed for economic, technical and environmental feasibility. The comprehensively sustainability feasibility of these systems is conducted taking into account the cost, energy generation, CO_2 emissions and renewable fraction. Radar plot is employed to integrate all the sustainability indicators into a general indicator, which presents system's sustainability as a real number in the interval $[0, 2]$. Results show that for street lighting systems of all the cities, single crystal panel has a larger number of annual electricity generation, less emissions and higher environmental performance, but is more expansive than polycrystalline. It is also found that when the feed-in tariff higher than CNY1.27/kW h, the cost of energy of the solar-powered lighting systems is less than a pure grid-powered system. This will incite the use of solar PV in infrastructures. Through comparing the scores of sustainability, it is found that the Loudi system has the highest feasibility while the Yongzhou system has the lowest in the province.

14/03491 Thermal performance of turbulent flow in a solar air heater channel with rib-groove turbulators
Skullong, S. *et al. International Communications in Heat and Mass Transfer*, 2014, 50, 34–43.
This paper presents an experimental study on turbulent flow and heat transfer characteristics in a solar air heater channel fitted with combined wavy-rib and groove turbulators. The experiments are performed by controlling the airflow rate to obtain Reynolds numbers in the range of 4000 to 21,000. To produce recirculation flow in the tested channel having a constant heat-flux on the upper wall only, the triangular wavy ribs are placed repeatedly on the tested grooved channel walls. Three test cases of different rib-pitch to channel-height ratios (PR = P/H = 0.5, 1 and 2) with a single rib-to-channel height ratio (BR = b/H = 0.25) are introduced in the present work. The wavy ribs are placed with the attack angle of 45° relative to main flow direction. There are three types of rib arrangements, namely, rib-groove on the upper wall only, inline rib-groove, and staggered rib-inline groove on two principal walls. The experimental result reveals that the combined rib-groove on both the upper and lower walls of the test channel provides the highest heat transfer rate and friction factor in comparison with the smooth channel with/without ribs. However, the ribbed-grooved upper wall at PR = 0.5 yields the highest thermal performance. The combined rib-groove turbulator is found to be considerably higher thermal performance than the groove alone.

14/03492 Thermocline thermal storage systems for concentrated solar power plants: one-dimensional numerical model and comparative analysis
Modi, A. and Pérez-Segarra, C. D. *Solar Energy*, 2014, 100, 84–93.
Concentrated solar power plants have attracted increasing interest from researchers and governments all over the world in recent years. An important part of these plants is the storage system which improves dispatchability and makes the plant more reliable. In this paper, a one-dimensional transient mathematical model for a single-tank thermocline thermal energy storage system is presented. The model used temperature dependent correlations to obtain the thermophysical properties for the heat transfer fluid and considered heat loss through the tank wall. The effect of variation in important system parameters like the type of heat transfer fluid, the storage temperature difference and the cycle cut-off criterion on system performance was investigated. The results suggest that two important aspects for assessing the performance of the system are the cyclic behaviour of the system and the time required to attain equilibrium conditions. These aspects directly influence the discharge capacity and discharge power of the storage system, and therefore play an essential role in understanding the start-up characteristics of the system and provide an insight regarding the availability of storage when designing the power cycle for concentrated solar power applications. It was also observed that the cycle durations and the time required to attain cyclic conditions are highly sensitive to not only the storage temperature difference, but also the cut-off temperature difference.

14/03493 Thermodynamic evaluation of liquid metals as heat transfer fluids in concentrated solar power plants
Pacio, J. *et al. Applied Thermal Engineering*, 2013, 60, (1–2), 295–302.
Concentrated solar power, and in particular central receiver systems, can play a major role as a renewable energy source with the inherent possibility of including a thermal energy storage subsystem for improving the plant dispatchability. While current commercial projects are dominated by direct steam generation and molten nitrate salt concepts, next-generation systems will require higher operating temperature and larger heat-flux densities in order to increase the efficiency and reduce costs. In that context, liquid metals are proposed in this work as advanced heat transfer fluids that can face those challenges. The main advantages, regarding higher temperature and improved heat transfer performance, are discussed and quantified using simplified models. Indirect thermal storage solutions are proposed for compensating their relatively small heat capacity. Overall, provided that some practical challenges can be overcome, liquid metals present large potential as efficient heat transfer fluids.

Wind energy

14/03494 A combined fault ride-through and power smoothing control method for full-converter wind turbines employing supercapacitor energy storage system
Gkavanoudis, S. I. and Demoulias, C. S. *Electric Power Systems Research*, 2014, 106, 62–72.
As wind power installations are increasing in number, wind turbine generators (WTG) are required to have fault ride-through (FRT) capabilities. Recent grid operating codes demand that the WTGs stay connected during fault conditions, supporting the grid to recover back to its normal state quickly. However, forcing a WTG to remain connected during a grid fault has consequences on the conventional protection devices, as they might become blind to over-currents and short circuits. This paper proposes a new control algorithm combined with a power management method, which fulfils the demand to keep the WTG connected to the grid during a fault, but disconnects the WTG when the fault insists. The energy generated while riding through a grid fault, is stored in a supercapacitor energy storage system (SCESS). Furthermore, the SCESS is exploited for smoothing medium frequency wind power fluctuations, providing a high-quality power profile. The simulation results, which are performed on a 2 MW synchronous generator with external excitation, verify the proposed power management method.

14/03495 A numerical investigation into the influence of unsteady wind on the performance and aerodynamics of a vertical axis wind turbine
Danao, L. A. *et al. Applied Energy*, 2014, 116, 111–124.
Numerical simulations using Reynolds averaged Navier–Stokes-based computational fluid dynamics (CFD) have been utilized to carry out investigations on the effects of steady and unsteady wind on the performance of a wind tunnel scale vertical axis wind turbine (VAWT). Using a validated CFD model, steady wind simulations at $U_\infty = 7$ m/s were conducted and results have shown a typical performance curve prediction for this particular VAWT scale. Detailed flow physics are discussed showing the importance of stall and flow re-attachment on the performance of the turbine with unsteady winds. The three blades of the VAWT experience very different flow regimes as they rotate during a single periodic oscillation of the wind speed. When the VAWT operates in periodically fluctuating wind conditions, overall performance slightly improves if the following are satisfied: the mean tip speed ratio is just above the λ of the steady performance maximum, the amplitude of fluctuation is small (<10%), and the frequency of fluctuation is high (>1 Hz). Operation at a mean λ that is lower than λ for peak performance coefficient causes the VAWT to run in the λ band with deep stall and vortex shedding, to the detriment of the VAWT performance coefficient. Large fluctuations in wind speed causes the VAWT to run in λ conditions that are drag dominated, thus reducing the performance of the wind turbine. Within realistic conditions, higher frequencies of fluctuation marginally improve the performance of the VAWT.

14/03496 A survey on energy storage resources configurations in order to propose an optimum configuration for smoothing fluctuations of future large wind power plants
Jannati, M. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 158–172.
As the wind power capacity increases, the effect of wind power fluctuations on the system stability becomes more significant. Despite its high costs, utilizing energy storage resources such as batteries is inevitable in the smoothing process of wind power fluctuations. In a wind power plant, the place where batteries are located has considerable direct effect on their required capacity and thus on the initial investment cost. Therefore, in this paper a suitable configuration which significantly reduces the investment cost of the batteries is proposed and then the wind power fluctuation of a large wind power plant connected to a smart distribution grid is smoothed. Additionally, existing configurations for installing batteries in large wind power plants are investigated. The proposed configuration utilizes smart parks as aggregated storage resources in load side and an aggregated battery energy storage system with limited capacity at the plant side as well. Therefore, in addition to accurate smoothing of wind power fluctuations, the energy storage investment cost is reduced significantly utilizing the proposed configuration. Simulation studies in MATLAB software package are carried out to verify the performance of the proposed approach.

14/03497 Developing the full-field wind electric generator
Ting, C.-C. and Yeh, L.-Y. *International Journal of Electrical Power & Energy Systems*, 2014, 55, 420–428.
A conventional wind electric generator generally works with a fixed normal rated power (NRP). A gearbox to provide such a generator with the quasi-constant rotational speed to reach its maximum working efficiency is required. It is well known that an electric generator with large NRP also receives relatively small working efficiency while the input power is too small due to it needs gearbox with relatively larger speed ratio to reach the required rotational speed. In general, the larger the speed ratio of a gearbox, the larger the transmission loss. In other words, if the mechanical resistance is considered, the conventional wind electric generator actually loses a lot of energy in the slow wind speed field. To avoid the use of a gearbox with large speed ratio in the slow wind speed field, a special generator with changeable NRP should be used. This work presents a special wind electric generator

using the multi-layer magnetic cutting electric generator, which effectively works in full wind field with the help of the changeable NRP. The developed multi-layer magnetic cutting electric generator is the so-called disk or axial flux permanent magnet electric generator with multi-layer structure, which is mainly composed of the rotational axis, the rotational magnet frameworks, and the fixed electric coil frameworks. In process, the numbers of the active fixed electric coil frameworks are changeable due to the different numbers of the active fixed electric coil frameworks has the different NRP. In other words, the developed multi-layer magnetic cutting electric generator can automatically adjust its NRP to match various wind speeds and always reach the maximum working efficiency in the full wind field. The results show that the total working efficiency of the developed full-field wind electric generator has increased *ca*. 3%.

14/03498 Development of short-term reliability criterion for frequency regulation under high penetration of wind power with vehicle-to-grid support

Han, S. and Han, S. *Electric Power Systems Research*, 2014, 107, 258–267.

Existing reliability indices for power systems provide measures of long-term stability; in this work, the authors propose a new reliability criterion that estimates the probability of a spinning-reserve shortage occurring, thus indicating the short-term stability of the grid frequency. In the formulation, load, wind power, and vehicle-to-grid (V2G) power are represented as random variables, and conventional generators are incorporated in a deterministic manner. Using the equilibrium of demand and supply and the physical constraints of automatic generation control, two inequalities are derived, from which the probability of successful frequency regulation is obtained. The inverted probability, referred to as the failure rate for frequency regulation (FRFR), is employed as a metric in the short-term reliability criterion. Then, the developed criterion was applied in several case studies. First, the impact of wind-power deployment was estimated in terms of the required spinning reserve. The acceptable penetration level of wind power was then investigated in the case that V2G power is also present. The variation of FRFR with respect to the commitment level of thermal (non-renewable) power plants was also investigated under the renewable portfolio standard (RPS) to illustrate the recursive effect of the policy. Finally, FRFR was calculated for the IEEE reliability test system and compared with conventional reliability indices.

14/03499 Employing two novel mechanical fault ride through controllers for keeping stability of fixed speed wind generation systems hosted by standalone micro-grid

Kamel, R. M. *Applied Energy*, 2014, 116, 398–408.

This paper proposes and designs two novels fault ride through (FRT) controllers for maintaining fixed speed wind generation system (FSWGs) stability during fault events. The first technique has been implemented by increasing the wind turbine blade pitch angle with maximum possible rate to reduce the mechanical extracted wind power and consequently suppress wind generation system acceleration. The second FRT technique has been verified by adapting gear ratio of wind generation system to run far from optimum maximum power point and help FRT process. Effectiveness of the two proposed FRT techniques has been proven by accurate simulation of the most severe disturbance conditions. Also, results indicated that second technique gives faster response than the first one. Without employing any FRT technique, FSWGs cannot keep its stability and the standalone micro-grid transfers to the blackout mode. Implementation the two FRT techniques requires no additional hardware. Only, control algorithms need little modification to deal with fault event and help FRT process. This fact makes the two proposed FRT techniques are simple, practical and highly economical attractive.

14/03500 Error compensation in distance relays caused by wind power plants in the power grid

Trujillo Guajardo, *et al*. *Electric Power Systems Research*, 2014, 106, 109–119.

This article presents the Prony method as a filtering technique for distance relays. First, the effect of non-filtered frequency components generated by wind power plants in distance relays is evaluated in a simplified model of a doubly fed induction generator, resulting in an error of apparent impedance measurement. Then, the effects of non-filtered frequency components for typical distance relay are presented. The error in apparent impedance measurement is evaluated in reach and operation time of the relay; a distorted characteristic of the mho distance relay is shown in the impedance plane. Finally, Prony method as a filtering technique is implemented as a solution of the apparent impedance measurement error, and the simulated case and a real fault event are evaluated to validate the proposed distance relay algorithm. Thus the asynchronous frequency components of voltage and current signals are identified and filtered, as a result the performance of the distance relay is enhanced.

14/03501 Experimental evaluation of air-termination systems for wind turbine blades

Abd-Elhady, A. M. *et al*. *Electric Power Systems Research*, 2014, 107, 133–143.

In this paper, air-termination systems for wind turbine blades reported in IEC-61400–24 standard are evaluated experimentally. These systems are such as receptor, metallic mesh and metallic conductor on the blade edges. In addition to these systems, metallic cap on the blade tip is investigated. The lightning attachment manner to the wind turbine blade is studied under positive and negative impulse voltages and for polluted and unpolluted blade surfaces. As the blades are rotating, the experiments are conducted considering five positions with different angels. The protection evaluation is done using 2 m blade tip section that is a part of 19.1 m actual blade length of 600 kW wind turbine. According to the comparison between the above systems, a proposed air-termination system is developed and experimentally examined. The results show that the proposed system attains higher lightning protection efficiency. The tests are carried out using a designed blade tip section with applying standard lightning impulse voltages.

14/03502 Impact of ambient turbulence on performance of a small wind turbine

Lubitz, W. D. *Renewable Energy*, 2014, 61, 69–73.

High-resolution measurements of wind speed and energy generation from an instrumented Bergey XL.1 small wind turbine were used to investigate the effect of ambient turbulence levels on wind turbine energy production. It was found that ambient turbulent intensity impacts energy production, but that the impact is different at different wind speeds. At low wind speeds, increased turbulence appeared to increase energy production from the turbine. However, at wind speeds near the turbine furling speed, elevated turbulence resulted in decreased energy production, likely to turbulent gusts initiating furling events. Investigation of measurements recorded at 1 Hz showed a time lag of 1–2 s between a change in wind speed and the resulting change in energy production. Transient changes in wind speed of only 1 s duration did not impact energy production, however, longer duration changes in wind speed were tracked reasonably well by energy production.

14/03503 Macro-composites with star-shaped inclusions for vibration damping in wind turbine blades

Agnese, F. and Scarpa, F. *Composite Structures*, 2014, 108, 978–986.

The work describes the numerical and experimental assessment of using biphase composite structures with non-classical shape inclusions. Star-shaped biphase cells have been designed, modelled and tested to evaluate the complex engineering constants corresponding to various deformation modes. A finite element homogenization method using the complex modulus approach has been used to evaluate the variation of the storage moduli, loss factors and amounts of strain energy dissipated in the matrix versus the unit cell geometry parameters. Experimental results have been obtained on aluminium/cast epoxy sample using a shear dynamic test rig and a dynamic mechanical analyser. The results have been benchmarked against unit biphase composite configurations with cylindrical inclusions having the same contact surface between inclusion and matrix than the star-shaped reinforcements. The composite cells are intended for a possible use as structural damping units to be located in maximum nodal strain positions corresponding to specific wind turbine blade modes.

14/03504 Multi-area economic generation and reserve dispatch considering large-scale integration of wind power

Chen, C.-L. *et al*. *International Journal of Electrical Power & Energy Systems*, 2014, 55, 171–178.

Wind power penetration in the Taiwanese power system faces significant barriers due to limited transmission capability. One of the most important future challenges seems to be the management of the integration of fluctuations in the electricity production from wind energy sources. The problem is further complicated by the generation dispatch imposed by the presence of transmission capacity limits. Several new important concepts about economic dispatch model are investigated in this paper for the large-scale wind capacity integration. A penalty function-hybrid direct search method is also developed for the solution of multi-area wind-thermal co-ordination dispatch (MWCD) problem. Several important issues of wind capacity integration in the Taiwan power system are discussed by using the developed MWCD software. Numerical experiments are included to illustrate the impacts of transmission capacity limits on wind power penetration level in each area and to assess the impact and economic benefits of the installation of wind farms for the Taiwan power system.

14/03505 New approaches in harnessing wave energy: with special attention to small islands

Fadaeenejad, M. *et al*. *Renewable and Sustainable Energy Reviews*, 2014, 29, 345–354.

The application of renewable energies has increased rapidly in the previous decade to solve some problems such as growing energy demand and environmental issues. Wave power as a high potential renewable energy and is more predictable compared to other renewable sources. Although there are many research works about wave energy only a few of them consider a suitable wave energy converter as a power system for remote islands. The potential of wave energy for remote islands is discussed in this review by considering environmental impacts, various types of wave energy converters and applied wave power projects for various islands. The results show that wave energy plays a key role for sustainable development of offshore islands by considering the traditional views and environmental protection.

14/03506 Off-shore wind farm development: present status and challenges
Perveen, R. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 780–792.
Offshore wind farm (OWF) is an emerging technology in the wind energy conversion system. These wind resources are abundant, stronger, and are more consistent in terms of their availability than land-based wind resources. As a matter of fact significantly higher energy production is achieved due to larger wind turbine ratings and stronger wind profiles. This paper highlights the present scenario and challenges in development of offshore wind power. The challenges and opportunities that exist in the development stages of an offshore wind farm project, from exploration to erection and installation of wind turbines, construction of platforms and laying of sea cables, up to maintenance and decommissioning, involving important technical aspects are addressed. An application of high-voltage direct current transmission for integration of large-scale offshore wind farms with an onshore grid is attractive as compared to high-voltage alternating current transmission systems. To make the offshore wind farms feasible, reliable and secure, the different aspects in planning, design and operation are also reviewed in this paper.

14/03507 Optimum insulation thickness for external walls on different orientations considering the speed and direction of the wind
Axaopoulos, I. *et al. Applied Energy*, 2014, 117, 167–175.
Thermal insulation is generally installed in the envelope of residential buildings to improve their thermal performance. However, the selection of the optimum insulation thickness requires a detailed thermal energy and economic analysis. This paper determines the optimum insulation thickness for external walls of different composition and orientation, considering both the heating and cooling period and taking into account the wind speed and direction. Three types of composite, thermally insulated walls have been selected. Annual heating and cooling transmission loads are being calculated based on transient heat flow through the external walls and by using hourly climatic data of the city of Athens, Greece. The available wind speed and direction data have been statistically analysed for the assessment of the prevalent wind directions in the area. An economic analysis, based on the life cycle savings method has been performed for each configuration, various thicknesses of insulation material and different orientations. The optimum insulation thickness for any type of wall and orientation was found to be between 7.1 and 10.1 cm. Furthermore, a sensitivity analysis indicates whether changes of the economic parameters affect the optimum insulation thickness.

14/03508 Real-time replication of a stand-alone wind energy conversion system: error analysis
Vlad, C. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 55, 562–571.
This paper provides information about the problem of real-time replication in laboratory conditions. The dynamic behaviour of a standalone low-power wind energy conversion systems (WECS) in response to the wind speed variations and also to the electrical load variations is replicated. The investigated system consists of a variable-speed wind turbine based on a permanent-magnet synchronous generator, a diode bridge rectifier, a DC–DC step-down converter and a wide range DC load. Because of reduced noise level and better steady-state accuracy, a speed-driven hardware-in-the-loop physical WECS simulator has been used to accomplish this task. Its main drawback – that is, a reduced bandwidth – has been significantly alleviated by using an enhanced software simulator structure which uses a feed-forward compensation of the inherent physical disturbance produced by the generator torque variations. Both time-domain experimental results and a thorough frequency-domain error analysis show good replication performance in the frequency range of variation of both wind speed and electrical load.

14/03509 Statistical distribution for wind power forecast error and its application to determine optimal size of energy storage system
Wu, J. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 55, 100–107.
Accurate wind power forecast is an important tool for wind farm to participate in day-ahead or hours-ahead energy markets. However, forecast errors with any methodology are so large that they cannot be neglected. The forecast error needs to be analysed individually for single wind farm to estimate the impact of this error on trading wind energy in electricity market. Although forecast error is always assumed as normal distribution, it can be demonstrated that it is not proper with a simple statistical analysis. In this paper, a mixed distribution is proposed based on Laplace and normal distribution to model forecast errors associated with persistence forecast for single wind farm over multiple timescales. Then the proposed distribution is used to estimate the penalties for prediction errors in the electricity market. Energy storage system (ESS) can smooth the wind power output and make wind power more 'dispatchable'. A probabilistic method is proposed to determine optimal size of ESS for wind farm in electricity markets. The results indicate that the proposed distribution and probabilistic method is efficient to find optimal size of ESS.

14/03510 WRF wind simulation and wind energy production estimates forced by different reanalyses: comparison with observed data for Portugal
Carvalho, D. *et al. Applied Energy*, 2014, 117, 116–126.
The performance of a weather research and forecast (WRF) mesoscale model of wind simulation and wind energy estimates was assessed and evaluated under different initial and boundary forcing conditions. Due to the continuous evolution and progress in the development of re-analyses datasets, this work aims to compare an older, yet widely used, re-analysis (the NCEP-R2) with three recently released re-analyses datasets that represent the new generation of this type of data (ERA-Interim, NASA-MERRA and NCEP-CFSR). Due to its intensive use in wind energy assessment studies, the NCEP-GFS and NCEP-FNL analysis were also used to drive WRF and its results compared to those of the simulations driven by re-analyses. Six different WRF simulations were conducted and their results compared to measured wind data collected at thirteen wind measuring stations located in Portugal in areas of high wind energy potential. Based on the analysis and results presented in this work, it can be concluded that the new generation re-analyses are able to provide a considerable improvement in wind simulation when compared to the older re-analyses. Among all the initial and boundary conditions datasets tested here, ERA-Interim re-analysis is the one that likely provides the most realistic initial and boundary data, providing the best estimates of the local wind regimes and potential wind energy production. The NCEP-GFS and NCEP-FNL analyses seem to be the best alternatives to ERA-Interim, showing better results than all the other re-analyses datasets here tested, and can therefore be considered as valid alternatives to ERA-Interim, in particular for cases where reliable forcing data is needed for real-time applications due to its fast availability.

Others, including economics

14/03511 A hybrid method for simultaneous optimization of DG capacity and operational strategy in microgrids utilizing renewable energy resources
Moradi, M. H. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 56, 241–258.
Recently, microgrids have attracted considerable attention as a high-quality and reliable source of electricity. In this work energy management in microgrids is addressed in light of economic and environmental restrictions through (a) development of an operational strategy for energy management in microgrids and (b) determination of type and capacity of distributed generation sources as well as the capacity of storage devices based on optimization. Net present value (NPV) is used as an economic indicator for justification of investment in microgrids. The proposed NPV-based objective function accounts for the expenses including the initial investment costs, operational strategy costs, purchase of electricity from the utility, maintenance and operational costs, as well as revenues including those associated with reduction in non-delivered energy, the credit for reduction in levels of environmental pollution, and sales of electricity back to the utility. The optimal solution maximizing the objective function is obtained using a hybrid optimization method which combines the quadratic programming and the particle swarm optimization algorithms to determine the optimum capacity of the sources as well as the appropriate operational strategy

for the microgrid. Application of the proposed method under different operational scenarios serves to demonstrate the efficiency of the proposed scheme.

14/03512 A novel method for reliability assessment of autonomous PV-wind-storage system using probabilistic storage model

Paliwal, P. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 55, 692–703.

The deployment of energy storage has emerged as most viable alternative for maintaining reliability of renewable energy-based autonomous power systems. The intermittent nature of renewable energy sources (RES) and their increased penetration in recent times makes reliability assessment studies particularly significant. This paper proposes a novel probabilistic model for battery storage systems to effectively facilitate implementation of analytical technique for reliability assessment of RES-based systems incorporating battery storage. The proposed probabilistic battery state model comprises of multiple states of battery state of charge and probability associated with each state. The developed model takes into account variable nature of RES and their corresponding effect on storage systems. In order to demonstrate the effectiveness of proposed analytical technique, reliability assessment studies have been carried out for a hypothetical autonomous photovoltaic–wind storage system located in Jaisalmer, Rajasthan, India. The results obtained have been compared with Monte Carlo simulation in order to establish the superiority of proposed approach.

14/03513 An economic and environmental assessment for selecting the optimum new renewable energy system for educational facility

Hong, T. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 286–300.

With the world's attention focused on climate change, the United Nations Framework Convention on Climate Change provides the basis for global action to encourage sustainable development. A wide variety of measures are being taken in South Korea in line with this trend, but new and renewable energy (NRE) have been highlighted as sustainable energy sources. This study aims to assess the economic and environmental effects of the use of NRE for selecting the optimum NRE system in educational facilities. Towards this end, the following were done: (i) selection of a facility and its applicable NRE system type; (ii) calculation of the energy generation by the NRE systems via energy simulation; (iii) life cycle cost analysis for the economic evaluation on the NRE systems; (iv) life cycle assessment for the environmental evaluation on the NRE systems; (v) using the net present value and the savings-to-investment ratio, comprehensive evaluation of the economic and environmental effects on the NRE systems. The results of this study can be used to (i) determine which NRE system is most appropriate for educational facilities; (ii) calculate the payback period for a certain investment; (iii) decide which location is proper for the implementation of an NRE system considering the characteristics of the regional climate and (iv) select energy- and cost-efficient elementary schools where the NRE system can be applied.

14/03514 Bioenergy villages in Germany: bringing a low carbon energy supply for rural areas into practice

Jenssen, T. *et al. Renewable Energy*, 2014, 61, 74–80.

An increasing number of rural municipalities wants to meet their entire energy demand with biomass. This article gives a system analytic view on these 'bioenergy villages' by balancing pros (reduction of CO_2 emissions) and cons (increasing costs, land use) using the example of a model municipality in Germany. The results indicate that a 100% energy supply based on biomass from within the boundaries of a rural municipality is technically possible but less reasonable with respect to land-use competition and costs of energy supply. Whereas heat and power demand in bioenergy villages can be covered with relatively little land use and to relatively low costs, the production of transport fuel based on energy crops (rape seed) leads to significant negative impacts. For a cost-efficient decarbonization of rural areas it can therefore be recommended to particularly expand the utilization of biomass for heat and power production and to reconsider transport fuel production.

14/03515 Comparing push and pull measures for PV and wind in Europe

Laleman, R. and Albrecht, J. *Renewable Energy*, 2014, 61, 33–37.

Successful technological innovation frameworks are based on synergistic packages of technology-push and demand-pull measures. As the massive deployment of premature renewable energy technologies risks becoming very expensive, the debate on the optimal trajectory of renewable technologies should explicitly consider the balance between deployment incentives and research and development (R&D) efforts. This paper explores this balance regarding wind and photovoltaic (PV) technology support in Europe. Based on rather conservative estimates, the authors calculate future deployment costs and compare these figures to the current public investments in PV and wind R&D. It was found that, today, for each euro spent on R&D to develop future technologies, €35–41 are spent on the deployment of existing technologies. Furthermore, private PV and wind technology companies tend to underinvest in R&D for various reasons. In an alternative scenario, the optimal R&D efforts for the PV and wind sectors were assessed based on a 7% R&D-to-sales benchmark typical for engineering sectors. If public R&D efforts increased according to this benchmark, and hence compensate for the private underinvestments in R&D, pull/push ratios between 6 and 8 could be achieved. This leads to the conclusion that the current balance between deployment and R&D is far from optimal.

14/03516 Corn stover for bioenergy production: cost estimates and farmer supply response

Thompson, J. L. and Tyner, W. E. *Biomass and Bioenergy*, 2014, 62, 166–173.

A great deal of attention is being paid to potential use of corn stover as a feedstock for bioenergy production. In addition to meeting renewable energy goals, use of corn stover for energy production may provide a new source of income for corn growers. This study estimates the costs of corn stover harvest and supply, and then uses that information to estimate farm production decisions and changes to farm profit at varying corn stover prices. In this study, corn stover is collected in large round bales using a raking, baling, and staging method. Harvest cost includes payments for fuel, labour, equipment ownership and repair, net wrap and nutrient replacement. Supply costs include storage, loading and unloading, and transport. The total cost of harvest and supply is estimated between 82.19 (dry) and 100.56 $\$\,Mg^{-1}$ (dry). Costs will vary considerably from farm to farm and from year to year depending on weather conditions. A linear programming model was used to estimate the willingness of corn growers to harvest corn stover at varying stover prices. Corn stover supply, farm profit, and land allocation was analysed under multiple scenarios. At a price of $88.19\,\$\,Mg^{-1}$, farms in the base case harvested corn stover at a rate of $2.49\,Mg\,ha^{-1}$ using a 33% removal rate. At this price, stover provided enough additional profit to entice farmers to shift to more continuous corn production. Future research is needed to determine the overall impacts of a viable stover market on corn and soybean production and price.

14/03517 Cost-potential curves for onshore wind energy: a high-resolution analysis for Germany

McKenna, R. *et al. Applied Energy*, 2014, 115, 103–115.

Germany has set itself some very ambitious targets for energy supply from renewable sources, including 80% of electricity by 2050. The favourable economic political framework for renewable technologies has led to the rapid expansion of onshore wind and other renewables in the past few years. Motivated by the lack of recent studies dealing with this issue, this paper determines the current potentials and costs for onshore wind in Germany. The developed methodology allocates a wind turbine to a specific location based on the prevailing wind conditions and the surface roughness, compared to previous studies, which assume that one or two turbines is/are installed overall. Cost–potential curves for wind energy are thus generated on a highly disaggregated level (at least $1\,km^2$) based on various discount rates. The technical potential is around 860 TWh/a and the associated generation costs lie in the range from 5 to 15 €¢/kWh, depending upon the degree of risk-adversity and cost of capital. This implies a currently economic potential of 400–800 TWh/a. The main uncertainties lie in the effect of small areas on the total potential. Further work should therefore focus on developing a clustering method for these small areas, considering the exact location of installed turbines and attempting to account for social barriers (and therefore social costs) to the development of wind energy.

14/03518 Efficiency of OWC wave energy converters: a virtual laboratory

López, I. and Iglesias, G. *Applied Ocean Research*, 2014, 44, 63–70.

The performance of an oscillating water column (OWC) wave energy converter depends on many factors, such as the wave conditions, the tidal level and the coupling between the chamber and the air turbine. So far most studies have focused on either the chamber or the turbine, and in some cases the influence of the tidal level has not been dealt with properly. In this work a novel approach is presented that takes into account all these factors. Its objective is to develop a virtual laboratory which enables to determine the pneumatic efficiency of a given OWC working under specific conditions of incident waves (wave height and period), tidal level and turbine damping. The pneumatic efficiency, or efficiency of the OWC chamber, is quantified by means of the capture factor, i.e. the ratio between the absorbed pneumatic power and the available wave energy. The approach is based on artificial intelligence – in particular, artificial neural networks (ANNs). The neural network architecture is chosen through a comparative study involving 18 options. The ANN model is trained and, eventually,

validated based on an extensive campaign of physical model tests carried out under different wave conditions, tidal levels and values of the damping coefficient, representing turbines of different specifications. The results show excellent agreement between the ANN model and the experimental campaign. In conclusion, the new model constitutes a virtual laboratory that enables to determine the capture factor of an OWC under given wave conditions, tidal levels and values of turbine damping, at a lower cost and in less time than would be required for conventional laboratory tests.

14/03519 Energy and economic evaluation of a poplar plantation for woodchips production in Italy

Manzone, M. *et al. Biomass and Bioenergy*, 2014, 60, 164–170.

In Europe, farmers prefer the very short rotation coppice (vSRC) cultivation model, with a very high plant density (5500–14,000 p ha^{-1}) and a harvesting cycle of 1–4 years; while in Italy, recently, the farmers prefer the short rotation coppice (SRC) method, with a high plant density (1000–2000 p ha^{-1}) and a harvesting cycle of 5–7 years. This is because the most recent poplar hybrids have enhanced productivity and improved the biomass quality (calorific value), as a result of a better wood/bark ratio. In order to evaluate, from the energy and economic point of view, a poplar SRC, in the river Po Valley, an *ad hoc* study was made and a specific model was developed. On the basis of this cultivation technique, an energy and economic evaluation of a poplar SRC in northern Italy was realized. In detail, were considered data of poplar growth, in a plantation for the production of 6-year whips, in western Po Valley, considering a SRC duration of 6 years and a biomass (15 Mg ha^{-1} dry matter – DM per year) harvest at the end of cycle (6 years). In this computing system it was pointed out that the SRC is very interesting from an energy point of view, since the output/input ratio results to be higher than 18. The same is not true for the poplar SRC from an economic point of view. In order to obtain economic SRC sustainability, the biomass price should be at least €115 Mg^{-1} DM. A large biomass diffusion will be possible only with an increase of the biomass market value, or with economic sustain for its production.

14/03520 Feasibility analysis of offshore renewables penetrating local energy systems in remote oceanic areas – a case study of emissions from an electricity system with tidal power in Southern Alaska

Li, Y. and Willman, L. *Applied Energy*, 2014, 117, 42–53.

In many remote areas, expensive fossil fuels such as diesel are used to meet local electricity demand. However, their environmental impact is significant. Consequently, some of these areas have started to use hybrid systems that combine renewable energy sources and fossil fuel generation, such as wind–diesel systems, although wind is not feasible in some remote locations and fossil fuels remain the only resource in these areas. Fortunately, offshore renewable energy sources are available in many remote areas close to the ocean. In order to understand the feasibility of using offshore renewables in remote oceanic areas, the authors recently conducted a systematic study by developing an integrated model. This model includes a supply module, demand module, environmental impact module, and integrating module. Using this model, they mainly study the reduction in emissions resulting from offshore renewable energy penetration in local energy systems. In this paper, the authors present this integrated model and an example study of tidal energy in the southern Alaskan community of Elfin Cove, which relies on diesel fuel for all of its electricity requirements. With 56 kW of tidal power penetrating the energy system, it was found that almost 12,000 gallons of diesel fuel are displaced a year. This results in an annual emissions reduction of almost 244,000 lb CO_2 and about 1400 lb CO, as well as considerable reductions of particulate matter (PM-10), NO_x, and SO_x. The newly developed integrated model is expected to be used to analyse other aspects of tidal energy (and offshore renewable energy in general) in remote areas. For example, since the electricity demand in some remote areas varies significantly throughout the year, the authors recommend that tidal power should be used with a storage system.

14/03521 Hybridisation optimization of concentrating solar thermal and biomass power generation facilities

Peterseim, J. H. *et al. Solar Energy*, 2014, 99, 203–214.

Recently, the first concentrating solar power–biomass hybrid power plant commenced operation in Spain and the combination of both energy sources is promising to lower plant investment. This assessment investigates 17 different concentrating solar power–biomass hybrid configurations in regards their technical, economic and environmental performance. The integration of molten salt thermal storage is considered for the best performing hybrid configuration. While thermal storage can increase plant output significantly even 7 h full-load thermal storage plants would generate the majority of the electricity, 70%, from the biomass resource. Only mature technologies with references >5 MWe are considered in this assessment to ensure that the scenarios are bankable. The concentrating solar power technologies selected are parabolic trough, Fresnel and solar tower while the biomass systems include grate, fluidized bed and gasification with producer gas use in a boiler. A case study approach based on the annual availability of 100,000 t of wood biomass is taken to compare the different plant configurations but the results are transferable to other locations when updating site and cost conditions. Results show that solar tower–biomass hybrids reach the highest net cycle efficiency, 32.9%, but that Fresnel–biomass hybrids have the lowest specific investment, AU$4.5 m/MWe. The investment difference between the 17 scenarios is with up to 31% significant. Based on the annual electricity generation CSP–biomass hybrids have an up to 69% lower investment compared to standalone concentrating solar power systems. The scenario with the best technical performance, being solar tower and gasification, is at this point in time not necessarily the best commercial choice, being Fresnel and fluidized bed, as the lower Fresnel investment outweighs the additional electricity generation potential solar towers offer. However, other scenarios with different benefits rank closely.

14/03522 Impact of mergers and acquisitions on stock prices: the U.S. ethanol-based biofuel industry

Khanal, A. R. *et al. Biomass and Bioenergy*, 2014, 61, 138–145.

Corporate restructuring activities in the form of mergers and acquisitions (M&As) are on-going in the US ethanol-based biofuel industry. With regard to M&As, a widespread concern is about financial performance of an individual firm and stable financial performance of the overall industry. Using an event analysis method, this study explores the impact of recent M&As on stock prices and value of the firm of publicly traded ethanol-based biofuel industry between 2010 and 2012 in the USA. Results regarding the average cumulative abnormal returns of acquiring firms suggest that the market positively responded toward recent M&As in the industry. Around 4% positive growth on a 60-day event window was attributed to M&As using market-adjusted market portfolio. A significant positive 0.47% gain in cumulative returns in a 4-day event window and a 2.7% positive gain in a 10-day event window were suggested by this study.

14/03523 Intelligent control of a grid-connected wind-photovoltaic hybrid power systems

Hong, C.-M. and Chen, C.-H. *International Journal of Electrical Power & Energy Systems*, 2014, 55, 554–561.

A grid-connected wind–photovoltaic (PV) hybrid power system is proposed, and the steady-state model analysis and the control strategy of the system are presented in this paper. The system consists of the PV power, wind power and an intelligent power controller. The general regression neural network (GRNN) algorithm is applied to the PV generation system, which has non-linear characteristic and analysed performance. A high-performance on-line training radial basis function network-sliding mode (RBFNSM) algorithm is designed to derive the turbine speed in order to extract the maximum power from the wind. To achieve a fast and stable response for the power control, the intelligent controller consists of a RBFNSM and a GRNN for maximum power point tracking (MPPT) control. The pitch angle of the wind turbine is controlled by RBFNSM, and the PV system uses GRNN, where the output signal is used to control the boost converters to achieve the MPPT. The simulation results confirm that the proposed hybrid generation system can provide high efficiency with the use of MPPT.

14/03524 Low head pico hydro turbine selection using a multi-criteria analysis

Williamson, S. J. *et al. Renewable Energy*, 2014, 61, 43–50.

Turbine types suit specific ranges of head, flow rate and shaft speed and are usually categorized by specific speed. In the pico range, under 5 kW, the requirements are often different to that of larger scale turbines and qualitative requirements become more influential in selection. Pico hydro turbines can be applied beyond these conventional application domains, for example at reduced heads, by using non-traditional components such as low speed generators. This paper describes a method to select which turbine architecture is most appropriate for a low-head pico hydro specification using quantitative and qualitative analyses of 13 turbine system architectures found in the literature. Quantitative and qualitative selection criteria are determined from the particular requirements of the end user. The individual scores from this analysis are weighted based on the perceived relative importance of each of the criteria against the original specification and selects a turbine variant based on the total weighted score. This methodology is applied to an example of a remote site, low head and variable flow requirement, leading to the selection of a propeller turbine variant or single-jet Turgo turbine for this specification.

14/03525 Meta-analysis of high penetration renewable energy scenarios

Cochran, J. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 246–253.

This study provides a meta-analysis of several recent analytical studies that evaluate the possibility, operability and implications of high levels of renewable sources of electricity (RES-E) in power systems. These studies span different geographic regions, rely on a range of analytical methods and data assumptions, and were conducted with differing objectives. Despite the differences, these studies share some common conclusions, one of which is that renewable energy resources can play a large role in future power systems. Moreover, most of the studies address aspects of integrating these resources into system operations, and all of them conclude that RES-E can supply, on an hourly basis, a majority of a country's or region's electricity demand. This study compares the analytic approaches, data inputs, and results in an effort to provide additional transparency and information to policy makers.

14/03526 Methods for predicting seabed scour around marine current turbine

Chen, L. and Lam, W.-H. *Renewable and Sustainable Energy Reviews*, 2014, 29, 683–692.

Marine energy sources are able to make significant contributions to future energy demands. Marine current has huge potential to supply renewable energy as compared to the other energy sources. The marine environment is harsh for the installation and operation of marine current turbines (MCT). Seabed scour around MCT is induced when the flow suppression occurs at the seabed. Seabed scour is widely recognized as a difficult engineering problem which is likely to cause structural instability. This study found that the previous works mainly focus on the bridge piers, wind turbines and scour induced by ship propeller jets. Little information to date was found to predict the MCT-induced scour. The present paper proposes the potential equations to predict the MCT-induced scour. The study also recommends the consideration of the rotor into the existing equations for future research.

14/03527 On a near-optimal control approach for a wave energy converter in irregular waves

Korde, U. A. *Applied Ocean Research*, 2014, 46, 79–93.

Real-time smooth reactive control and optimal damping of wave energy converters in irregular waves is difficult in part because the radiation impulse response function is real and causal, which constrains the frequency-dependent added mass and radiation damping according to the Kramers–Kronig relations. Optimal control for maximum energy conversion requires independent synthesis of the impulse response functions corresponding to these two quantities. Since both are non-causal (one being odd and other even), full cancellation of reactive forces and matching of radiation damping requires knowledge or estimation of device velocity into the future. To address this difficulty and the non-causality of the exciting force impulse response function, this paper investigates the use of propagating-wave surface elevation up-wave of the device to synthesize the necessary forces. Long-crested waves are assumed, and the approach is based on the formulations produced in earlier studies. A predominantly heaving submerged device comprised of three vertically stacked discs driving a linear power take-off is studied. The overall formulation leads to smooth control that is near-optimal, given the approximations involved in the time-shifting of the non-causal impulse response functions and the consequent up-wave distances at which wave surface elevation is required. Absorbed power performance with the near-optimal approach is compared with two other cases, (i) when single-frequency tuning is used based on non-real time adjustment of the reactive and resistive loads to maximize conversion at the spectral peak frequency, and (ii) when no control is applied with damping set to a constant value. Simulation results for wave spectra over a range of energy periods and significant wave heights are compared for the three situations studied. While practical implementation presents engineering challenges, in terms of time-averaged absorbed power, unconstrained near-optimal control is found to perform significantly better than single-frequency tuning in the spectra with longer energy periods (>10 s for the present device), and somewhat better in the spectra with shorter energy periods (here ≤ 10 s).

14/03528 Preliminary design of the OWEL wave energy converter pre-commercial demonstrator

Leybourne, M. *et al. Renewable Energy*, 2014, 61, 51–56.

The consortium responsible for the next stage of development of the Offshore Wave Energy Limited (OWEL) wave energy converter will construct and test a large scale, pre-commercial demonstrator. It is expected that this will be installed at wave hub during 2013 and grid connected for a testing period lasting around 12 months. This paper reports on the preliminary design work being undertaken in the development of the marine demonstration device. This concentrates primarily on producing a fully costed design by detailing the hydraulic design and aspects of stability as well as providing insight into various design features such as the power take-off, naval architecture, moorings and control. The design is being largely informed by the results of a 15-month research project in which the performance was determined and a detailed techno-economic model for a large-scale OWEL device was generated.

14/03529 Redox flow batteries for the storage of renewable energy: a review

Alotto, P. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 325–335.

The need for grid-connected energy storage systems will grow worldwide in the future due to the expansion of intermittent renewable energy sources and the inherent request for services of power quality and energy management. Electrochemical storage systems will be a solution in many applications because of their localization flexibility, efficiency, scalability and other appealing features. Among them, redox flow batteries (RFBs) exhibit a very high potential for several reasons, including power/energy independent sizing, high efficiency, room temperature operation and an extremely long charge/discharge cycle life. RFB technologies make use of different metal ion couples as reacting species. The best-researched and already commercially exploited types are all-vanadium redox batteries, but several research programmes on other redox couples are underway in a number of countries. These programmes aim at achieving major improvements resulting in more compact and cheaper systems, which can take the technology to a real breakthrough in stationary grid-connected applications.

14/03530 Regulation for renewable energy development: lessons from Sri Lanka experience

Wijayatunga, P. D. C. *Renewable Energy*, 2014, 61, 29–32.

This paper examines the key features of the renewable energy development environment in Sri Lanka which led to the sector's rapid expansion. The recent development framework of the renewable energy sector was based on the importance of using indigenous resources, recognizing the positive environmental impacts and the avoidance of high-cost alternative thermal generation. This framework also recognized the pioneering effort of the developers in site identification by giving rights to develop on a first-come first-served basis. The policy framework was later extended with a renewable energy portfolio standard to achieve 10% of power generation through renewable energy. The standard power purchase arrangements reduced the transaction costs. The feed-in tariffs originally based on avoided costs later shifted to cost based, technology specific tariffs encouraging diversification of the renewable energy portfolio. The introduction of net-metering for renewable energy based distributed generation and the limited interventions in the form of green-tariffs also assisted the renewable energy development. The paper concludes that the policy and regulatory frameworks and different approaches to implementing them have been mostly successful experiences in Sri Lanka and they would provide useful lessons for similar countries when formulating and implementing related polices, regulations and legal frameworks.

14/03531 Renewable energy potential on marginal lands in the United States

Milbrandt, A. R. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 473–481.

This study identifies several marginal land categories suitable for renewable energy development, representing about 11% of the US mainland. The authors define marginal lands as areas with inherent disadvantages or lands that have been marginalized by natural and/or artificial forces. These lands are generally underused, difficult to cultivate, have low economic value and varied developmental potential. The study finds that a significant potential exists for renewable energy development on these lands. Technologies assessed include utility-scale photovoltaics (PV), concentrating solar power (CSP), wind, hydrothermal geothermal, mini-hydro systems (low head/low power), biomass power and landfill gas-to-energy. Solar technologies present the highest opportunity, followed by wind and biomass power. It is estimated that about 4.5 PWh of electricity could be produced from PV on marginal lands in the conterminous USA, 4 PWh from CSP, 2.7 PWh from wind, 1.9 PWh from biomass, 11 TWh from mini-hydropower systems, 8.8 TWh from hydrothermal geothermal and 7.3 TWh from landfill gas. While it is possible for some technologies to be co-located, it is more likely that only one will be deployed in a given area. Thus, it is most reasonable to view the potential for different technologies separately.

14/03532 Sizing and simulation of a photovoltaic-wind energy system using batteries, applied for a small rural property located in the south of Brazil

Nogueira, C. E. C. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 151–157.

This paper presents a methodology for sizing and simulating an autonomous photovoltaic-wind hybrid energy system with battery storage, using simulation tools and linear programming. The developed model is useful for energizing remote rural areas and produces a

system with minimum cost and high reliability, based on the concept of loss of power supply probability (LPSP), applied for consecutive hours. To calculate the solar power and the wind power, a statistical model based on Beta and Weibull probability density functions, respectively, is used. Some scenarios are calculated and compared, using different numbers of consecutive hours and different LPSP values. As a result, a complete sizing of the system and a long-term cost evaluation are presented.

14/03533 Tidal stream energy impact on the transient and residual flow in an estuary: a 3D analysis

Sánchez, M. *et al. Applied Energy*, 2014, 116, 167–177.

Interest in the exploitation of tidal stream energy has increased significantly over the past few years and several tidal farms have been proposed. In spite of this, only a few studies have dealt with the potential impacts on the environment resulting from the extraction of this energy, most of them by using two-dimensional (2D) numerical models. However, some of the areas of interest for tidal stream exploitation, such as the Galician Rias, present complex transient and residual circulation patterns which in turn result in one of the largest oceanic productivities in the world and whose potential changes cannot be properly studied by means of 2D models. In this work, a three-dimensional (3D) numerical model was implemented in Ria de Ortigueira, a promising region for tidal stream energy exploitation, to study the potential flow changes due to the operation of a power plant, including the assessment of the potential impacts on the 3D residual flow in a real estuary. First, the model was validated on the basis of current velocity measurements, then, it was used to describe the potential effects resulting from the operation of a previously proposed tidal stream farm during typical winter and summer conditions. For this purpose, the momentum sink approach was used. Overall, it was found that the resulting transient flow modifications were concentrated in the area occupied by and next to the farm, with nearly negligible effects outside the inner ria. Furthermore, important asymmetry effects were also observed; although the inner part of the estuary is flood dominated, the most important effects occur during the ebb as a result of the complex geometry of this area. Finally, the effects on the residual flow are of the same order, in terms of percentage of velocity variation, as in the case of the transient flow; however, they extend over a wider region, affecting the middle ria, where a complex 3D circulation pattern (a positive estuarine circulation) develops. Nevertheless, the operation of the tidal plant is not capable of modifying the general 3D flow structure in this area.

14/03534 Voltage control of stand-alone wind and solar energy system

Malla, S. G. and Bhende, C. N. *International Journal of Electrical Power & Energy Systems*, 2014, 56, 361–373.

This paper presents a wind and solar stand-alone hybrid energy system for remote area power system applications. The wind, solar, battery, fuel cell and dump load (i.e. aqua-electrolyser) are connected to the common dc bus. An ac load is connected to dc bus through a pulse width modulation (PWM) based inverter. Ac voltage at load bus can be maintained at rated value by regulating dc-link voltage (V_{dc}) at its reference value and by controlling modulation index of PWM inverter. Novel control algorithms are developed to maintain V_{dc} at its reference voltage irrespective of variations in wind speed, solar irradiance and load. Along with the regulation of V_{dc}, dc–dc converter (connected between battery and dc-link) acts as a maximum power point tracker (MPPT) for the photovoltaic (PV) array. Hence, an extradedicated MPPT circuit is not required to extract maximum power from PV. A control technique for the PWM inverter has been developed to make the line voltages balanced at the point of common coupling when the load is unbalanced. Hence, efforts are made to supply quality voltage to the consumers through the stand-alone power system. Detailed modelling of various components of stand-alone system is presented. Extensive simulation results using Matlab/SIMULINK established that the performance of the controllers is quite satisfactory under balanced as well as unbalanced load conditions. Moreover, results with real-time digital simulator are presented.

14/03535 Wind energy and natural gas-based energy storage to promote energy security and lower emissions in island regions

Zafirakis, D. and Chalvatzis, K. J. *Fuel*, 2014, 115, 203–219.

Usually, isolated and remote areas, such as islands, meet their electricity needs using oil-fired power generators. When available, natural gas can potentially substitute oil. Moreover, the high-quality wind energy potential found in many of these areas cannot be used extensively. Main reason is the operation of small-scale, weak electricity grids which cannot cope with wind energy intermittency. To compensate for that, the authors examine the combination of wind energy and energy storage. For the latter, they focus on the technology of compressed air energy storage (CAES), which is suitable for scalable applications. To ensure the highest level of demand satisfaction, while avoiding system oversizing, the authors recommend a novel wind–CAES system that allows the switch from the CAES to the Brayton cycle when the stored energy is inadequate to meet demand. They developed a new algorithm for the sizing of such configurations, and used it on a case study that included a typical, medium-scale Aegean Sea island in combination with three representative wind regimes. The results demonstrate that even in areas with relatively low-quality wind potential there are significant improvements in fuel use reduction, CO_2 emissions and strengthening of energy supply security, while for island regions with higher-quality wind potential, the proposed solution also becomes cost-effective in comparison to other alternatives.

14 FUEL SCIENCE AND TECHNOLOGY

Fundamental science, analysis, instrumentation

14/03538 A comparative analysis of different dual problems in the Lagrangian relaxation context for solving the hydro unit commitment problem

Finardi, E. C. and Scuzziato, M. R. *Electric Power Systems Research*, 2014, 107, 221–229.

This paper presents a comparative analysis of two different solution strategies to the hydro unit commitment and loading (HUCL) problem with cascaded and head-dependent reservoirs. Both the dualization schemes are based on the Lagrangian relaxation (LR) technique, which supplies a lower bound for the optimal value of the objective function and provides good starting points for heuristic searches to obtain good feasible primal solutions. The numerical results show that the LC dualization scheme gives the best dual cost values and shorter execution time. In order to combine the advantages of the LR dualization schemes used in this paper, an alternative approach has been suggested. It consists of aggregate some or all the variables using a simplified linear function, and then dualizing the resulting copy constraints. Similarly, another idea that could be analysed is the use of the LC dualization solution as the starting point for the duplicate variable scheme or the opposite. It is important to point out that the conclusions concerning the differences of the two dualization schemes are problem dependent. In other words, for a different primal problem, the duplicate variable dualization scheme could perform better performance than the linking constraint one. Therefore, one important contribution of this paper is to present exhaustive analyses of two dual problem decompositions, which can be used to help one deciding the most efficient decomposition scheme. Finally, it is well known that the solution strategy performance of dual methodologies can be improved when good starting points are available. Then some initial values can be used as a warm-start, for example the optimal Lagrange multipliers obtained from the HUCL problem solution of a previous day or the solution of a HUCL simplified model.

14/03539 A dynamic compact thermal model for data center analysis and control using the zonal method and artificial neural networks

Song, Z. *et al. Applied Thermal Engineering*, 2014, 62, (1), 48–57.

Full-scale data centre thermal modelling and optimization using computational fluid dynamics (CFD) is generally an extremely time-consuming process. This paper presents the development of a velocity propagation method (VPM)-based dynamic compact zonal model to efficiently describe the airflow and temperature patterns in a data centre with a contained cold aisle. Results from the zonal model are compared to those from full CFD simulations of the same configuration. A primary objective of developing the compact model is real-time predictive capability for control and optimization of operating conditions for energy utilization. A scheme is proposed that integrates zonal model results for temperature and air flow rates with a proportional–integral–derivative controller to predict and control rack inlet temperature more precisely. The approach also uses an artificial neural network in combination with a genetic algorithm optimization procedure. The results show that the combined approach, built on the VPM-based zonal model, can yield an effective real-time design and control tool for energy efficient thermal management in data centres.

14/03540 A fuzzy-based approach for optimal allocation and sizing of capacitor banks

Ramadan, H. A. *et al. Electric Power Systems Research*, 2014, 106, 232–240.

This paper proposes a fuzzy set optimization approach for capacitor allocation in radial distribution system. In this approach, a membership function for voltage profile constraint has been used. Moreover, another membership function incorporating feeder section active power losses and total power losses constraints has been proposed. This membership function indirectly imposes thermal capability of the feeder on the optimization process. The proposed approach has been applied to nine- and 34-bus radial distribution systems. The results have been compared with those of two fuzzy approaches in literature. The comparison showed the effectiveness of the proposed approach for optimizing the sizes and locations of the capacitor with running and total cost reduction.

14/03541 A general method for developing friction factor formulas under supercritical conditions and in different geometries

Zang, J. *et al. Annals of Nuclear Energy*, 2014, 65, 262–271.

A general method for developing friction factor formulas in different geometries and under supercritical conditions was set up in this paper. The method was based on the two-layer wall function theory which could account for both the laminar viscous layer and turbulent layer. This characteristic led to its good agreement with empirical correlations in a wide range of Reynolds numbers, especially the prediction accuracy was improved at low Reynolds numbers in comparison with the previous work. This method could be extended to the flows over rough surfaces or with axial pressure gradient as long as the appropriate wall function is provided. Moreover, the wall function is based on a van Direst transformation which could take account of the fluid property variation across the boundary layer and thus the friction formula could be applied to supercritical flow. This formula could explain the special features of friction coefficient and showed good agreement with the experimental data performed by Nuclear Power Institute of China.

14/03542 A novel, comprehensive numerical simulation for predicting temperatures within boreholes and the adjoining rock bed

Gorman, J. M. *et al. Geothermics*, 2014, 50, 213–219.

Borehole creation involves complex thermal phenomena such as the injection of a fluid to cool the cutting tool and carry debris to the surface, generation of heat caused by the cutting tool and the thermal interactions between the flowing fluid and the stationary rock. These phenomena alter the temperature of the rock from its undisturbed state. An accurate characterization of the temperatures within the rock prior to the drilling operation is necessary for resource extraction, geothermal heat conduction calculations, and for paleoclimate studies. Disturbances in the rock temperature can lead to uncertainties in these calculated quantities and in the application of the inverse method. Presently, methods are available which treat the flowing fluid in a simplified manner, often as a stationary medium, and allow estimation of the temperature disturbances in the rock wall. Nevertheless, to the best knowledge of the authors, there are no published studies which fully include the fluid flow in the borehole during the drilling operation and its direct impact on temperatures. Additionally, the impact of the heat generation at the drill head on the temperatures in the fluid and the surrounding rock have not fully been studied. A method is proposed for determining temperatures within boreholes and the surrounding rock both during and after the drilling operation. The method encompasses all the issues listed above. It was discovered that the coolant temperature is dependent on the location within the borehole, and the relaxation time of rock temperatures to their equilibrium values varies with depth in the borehole.

14/03543 A rapid analytical assessment tool for three dimensional electrode microstructural networks with geometric sensitivity

Nelson, G. J. *et al. Journal of Power Sources*, 2014, 246, 322–334.

Electrochemical fin theory is applied to the microstructural analysis of $Sr_2Fe_{1.5}Mo_{0.5}O_{6-\delta}$, a redox stable solid oxide fuel cell electrode. The electrode microstructure is imaged by X-ray nanotomography, then partitioned into a network of resistive components with distinct geometric characteristics. The network is analysed using an analytical electrochemical fin network model. The resulting predictions of electrode performance are compared to predictions made using three-dimensional finite element simulations of charge transport with surface electrochemical reactions in the imaged microstructure. For a representative sub-volume of the structure, the electrochemical fin and finite element models provide comparable predictions. Analysis of larger representative volume elements extracted from the X-ray nanotomography data demonstrates good agreement with experimental measurements of the electrodes analysed. Finally, advantages of applying the analytical electrochemical fin network models to real microstructures are addressed, particularly with respect to significant reduction in memory requirements and computational time. The use of the electrochemical fin theory is able to rapidly analyse real microstructures with microstructural details that are comparable to finite element and lattice Boltzmann methods, but at volume sizes that finite element and lattice Boltzmann methods were not able to perform due to limits in memory and computational time.

14/03544 A study on ground-state energies of nuclei by using neural networks

Bayram, T. *et al. Annals of Nuclear Energy*, 2014, 63, 172–175.

One of the fundamental ground-state properties of nuclei is binding energy. Artificial neural networks (ANN) have been performed to obtain binding energies of nuclei based on the data calculated from Hartree–Fock–Bogolibov method with two Skyrme forces SLy4 and SKP. ANN has been employed to obtain two-neutron and two-proton separation energies of nuclei. Statistical modelling of ground-state energies using ANN has been seen as to be successful in this study. Particularly, predictive power of ANN has been drawn from estimations for energies of Sr, Xe, Er and Pb isotopic chains which are not seen before by the network. The study shows that such a statistical model can be possible tool for searching in systematic of nuclei beyond existing experimental data.

14/03545 A wave-by-wave analysis for the evaluation of the breaking-wave celerity

Postacchini, M. and Brocchini, M. *Applied Ocean Research*, 2014, 46, 15–27.

The paper gives an overall description of the breaking-wave celerity on the basis of a wave-by-wave analysis that has been performed by using field data collected during the ECORS Project (Truc Vert Beach, France, 2008). Data coming from two pressure sensors have been analysed with the aim to correlate, after a zero-crossing analysis, each wave of both signals. The method is based on a first correlation between 10-min time windows of both signals and, then, on the individuation of the correct time lag for each wave. Such data, which reveals a quasi-Gaussian behaviour of the breaking wave celerity, have also been used to relate the wave celerity with suitable wave characteristics, and comparisons are made with the most common formulas that can be found in the literature. The wave-by-wave method, validated by means of suitable laboratory test data, gives good results in the evaluation of the celerity, especially when it is made to depend on both a velocity scale and the wave non-linearity parameter. Further, a comparison with literature models used for the prediction of breaking wave celerity suggests good performances of both solitary-wave (correlation coefficient $R^2 = 0.79$) and shock-wave ($R^2 = 0.71$) theories, that give results well matched to the field data.

14/03546 Adaptive mesh refinement of gas–liquid flow on an inclined plane

Cooke, J. J. *et al. Computers & Chemical Engineering*, 2014, 60, 297–306.

Carbon dioxide capture and storage is one of the various methods that can be used to reduce the carbon footprint of the energy sector. The efficiency with which CO_2 is absorbed from flue gas using packed columns is highly dependent on the structure of the liquid films that form on the packing materials. This work examines the hydrodynamics of these liquid films using the computational fluid dynamics solver, OpenFOAM to solve two-phase, isothermal, non-reacting flow using the volume-of-fluid method. Local adaptive mesh refinement (AMR) is used to ensure improved resolution of the geometrical grids at the gas–liquid interface. Comparisons are made between the solutions obtained using AMR and those obtained using highly refined static meshes. It was observed that local AMR produced results with much better correlation to experimental data.

14/03547 Application of a multi objective multi-leader particle swarm optimization algorithm on NLP and MINLP problems

Shokrian, M. and High, K. A. *Computers & Chemical Engineering*, 2014, 60, 57–75.

This paper presents a modified particle swarm optimization algorithm for handling a variety of single and multi-objective mixed integer non-linear optimization problems that have equality and inequality constraints. An efficient multi-objective multi-leader particle swarm optimization algorithm is used to handle the extra objective imposed by a novel constraint handling method. In addition, a modified method of handling binary variables is used and the algorithm is adapted to update discrete variables independent from continuous variables using these methods. The algorithm was applied on several well-known test problems in the field of chemical engineering including the William Otto process. The results proved the applicability and the efficiency of

this method for handling single and multi-objective optimization problems in mixed integer and non-linear decision spaces arising in the field of chemical engineering.

14/03548 Developing a probabilistic tool for assessing the risk of overheating in buildings for future climates

Jenkins, D. P. *et al. Renewable Energy*, 2014, 61, 7–11.

The effect of projected climate change on building performance is currently a growing research area. Building designers and architects are becoming more concerned that buildings designed for the current climate might not provide adequate working and living environments in the coming decades. Advice is needed to guide how existing buildings might be adapted to cope with this future climate, as well as guidance for new building design to reduce the chances of the building failing in the future. The Low Carbon Futures Project, as part of the Adaptation and Resilience to Climate Change programme in the UK, is looking at methods of integrating the latest climate projections from the UK Climate Impact Programme into building simulation procedures. The main obstacle to this objective is that these projections are probabilistic in nature; potentially thousands of equally-probably climate-years can be constructed that describe just a single scenario. The project is therefore developing a surrogate procedure that will use regression techniques to assimilate this breadth of climate information into the building simulation process.

14/03549 Development of a novel energy-absorbing bolt with extraordinarily large elongation and constant resistance

He, M. *et al. International Journal of Rock Mechanics and Mining Sciences*, 2014, 67, 29–42.

This paper presents an innovation work on the development of a novel energy-absorbing bolt characterized by an extraordinarily large elongation and high constant resistance. The bolt has a compound structure consisting of a cone-like piston sliding inside an elastically-deformable sleeve pipe. The frictional resistance generated by the sliding of the cone body relative to the internal surface of the sleeve pipe was mathematically formulated which is dependent on the elastic property of the sleeve pipe, the geometry of the cone and the frictional properties of the sliding interface, and independent of the external loads under the static loading conditions. A dashpot element for the cone-sleeve relative motion, termed 'stick-slip element', was proposed in construction of the lumped-mass model of the bolt for development of the constitutive equations that exhibits a frequency-dependent frictional behaviour and a stick-slip oscillating response. The results from the static pull tests compared very well with the predicted working resistances, energy-absorbing capacity and elongations. The time-marching scheme of the bolt's impact load from the weight-dropping tests evolves with the pulsation response in the initial phase, stick-slip oscillation in the subsequent regime over which the dynamic energy is consumed, and a quasi-linear attenuation in the later phase. It demonstrates the fact that this bolt is robust in damping the dynamic load. The analytical work in this study provides solutions in the assessment of the large deformation and establishment of the forewarning precursors associated with deep mines.

14/03550 Evaluating the Chingshui geothermal reservoir in northeast Taiwan with a 3D integrated geophysical visualization model

Chang, P.-Y. *et al. Geothermics*, 2014, 50, 91–100.

This study assesses the Chingshui geothermal reservoir with a three-dimensional visualization model that integrates geophysical measurements with well logs. To re-evaluate the geothermal reservoir quantitatively, the authors reprocessed resistivity measurements from a series of studies conducted nearly 40 years ago, as well as from the magnetotelluric (MT) explorations performed recently in the Chingshui area. They established a three-dimensional (3D) visualization model that integrates these different geophysical survey results as well as the well-logs to better perform the spatial relationships between them. From the orthogonal bipole–bipole resistivity surveys, the authors have identified several regional conductive structures with resistivity of less than 50 Ω m representing the major fault zones of the Dahsi, Xiaonanao, and Chingshuihsi faults. Among them, the Chingshui fault is located along the Chingshuihsi River valley and is associated with hot spring features. The collinear Schlumberger survey along the Chingshuichi Valley identified three relatively conductive regions with resistivity of less than 20 Ω m. The MT interpretation shows that the structure associated with the geothermal reservoir extends from these near-surface fractures to a depth of −1500 m toward the south in the fault zone. The identified production zone from the core drilling records is consistent with the conductive structure in the MT inverted image. In addition, the structure seems to consist of two sub-regions: a somewhat shallow one at a depth of between −400 and −800 m in the north and a somewhat deep one at a depth of between −600 and −1500 m in the south. From the 3D model, it is estimated that the volume of the Chingshui geothermal reservoir is about 9.54×10^7 m^3. Given a gross porosity of 0.1 and 100% saturation for the fracture zones from the core logs, the inferred Chingshui geothermal reservoir contains about 10 million m^3 of geothermal fluids.

14/03551 Experimental investigation on pressure oscillations caused by direct contact condensation of sonic steam jet

Qiu, B. *et al. Experimental Thermal and Fluid Science*, 2014, 52, 270–277.

An experimental study has been carried out to investigate the pressure oscillation of the sonic steam jet in a pool. The exit diameter of the nozzle was 8 mm and the steam mass flux was 298–865 kg/(m^2 s), water temperature 20–70 °C. The dominant frequency and amplitude of pressure oscillation have been analysed. A theoretical model on pressure oscillation amplitude was set up and a semi-empirical correlation was given to predict the dimensionless root mean square amplitude of pressure oscillation. The pressure oscillation is mainly caused by the variation of steam speed δu, heat transfer coefficient δh and net steam-water interface δS. The dominant frequency of the pressure oscillation decreased with the increase of the water temperature while increased in CO region and decreased in SC region with the increase of the steam mass flux. The amplitude of the pressure oscillation is inversely proportional to the dominant frequency. The dominant frequencies did not change with the variation of x/d_e and r/d_e. But the amplitudes decreased with the increase of x/d_e and r/d_e. An empirical correlation was suggested to predict the dimensionless root mean square amplitude based on the experimental data. The predictions agreed well with the experiments, and the discrepancies were within ±30%.

14/03552 Experimental study on unstable free surface vortices and gas entrainment onset conditions

Cristofano, L. *et al. Experimental Thermal and Fluid Science*, 2014, 52, 221–229.

Free surface vortices formation has been, for many years, a relevant issue in many engineering applications with hydraulic intakes, since strong whirlpools introduce swirl flow at the intake causing entrainment of floating matters and gases (air or other gases). The gas entrainment (GE) phenomenon has also been an important topic in the nuclear industry in recent years, due to the possibility of free vortex formation at the surface, especially in sodium-cooled fast reactors. This phenomenon may result in an unlikely positive reactivity insertion accident, affecting the safety performances of the reactor itself. A gas entrainment test section experimental facility has been built in order to study free surface vortices occurrences. The main purpose of this facility is to understand the influence of different parameters on free surface vortices formation and evolution. Experimental tests and preliminary observations carried out with cold water as working fluid, different water level in the tank, circulating flow rate and outlet tube diameter, are presented as occurrence maps in this paper. The observed vortices have been qualitatively classified in different 'formation stages' and the most important parameters that influence the physical phenomenon have been identified through a dimensionless analysis. Empirical correlations based on dimensionless parameters of the transition boundaries between stages, including the onset of gas entrainment, have been developed and discussed, and very preliminary considerations on the sodium–water similitude, based on the Froude and Weber numbers, are introduced.

14/03553 Fatigue behaviour of metal pin-reinforced composite single-lap joints in a hygrothermal environment

Son, H.-G. *et al. Composite Structures*, 2014, 108, 151–160.

In this study, the fatigue behaviour of stainless steel pin-reinforced cocured composite single-lap joints in a hygrothermal environment was experimentally investigated. Specimens were exposed to a temperature of 71 °C and a relative humidity of 85% until moisture saturation was achieved. Fatigue tests were conducted on the specimens in three different environmental conditions (room temperature and dry, elevated temperature and dry, and elevated temperature and wet). Tension–tension cyclic loads were applied to the specimens with a stress ratio of 0.5 and the maximum stress levels ranging from 50% to 90% of the static strengths of the joints. The results showed that the fatigue strength of a z-pinned joint at a million cycles of repeated loads was improved up to 48.3% compared to that of a joint without z-pins for the elevated temperature and wet condition.

14/03554 Flicker characteristics of efficient lighting assessed by the IEC flickermeter

Azcarate, I. *et al. Electric Power Systems Research*, 2014, 107, 21–27.

This study presents an experimental study of the behaviour of modern lighting technologies under supply voltage fluctuations. Some studies have reported that flicker severity measurements could exceed the compatibility levels without leading to flicker complaints when modern lighting is in use. Such conclusions have resulted in two main proposals regarding the assessment of flicker: to relax the flicker compatibility

indexes and to adapt standardized procedures to assess flicker based on a new reference lamp instead of the current reference, the incandescent lamp. This work presents alternative tools for analysing the effect of efficient lighting on the assessment of flicker. The main findings challenge the assumption that efficient modern lighting is not sensitive to voltage fluctuations, at least over a considerable frequency range. Furthermore, the results oppose the use of the standardized functional model of the incandescent lamp for assessing the flicker severity produced by modern lamps.

14/03555 Hybrid method integrating agent-based modeling and heuristic tree search for scheduling of complex batch processes

Chu, Y. *et al. Computers & Chemical Engineering*, 2014, 60, 277–296.
The authors propose a hybrid method integrating agent-based modelling and heuristic tree search to solve complex batch scheduling problems. Agent-based modelling describes the batch process and constructs a feasible schedule under various constraints. To overcome myopic decisions of agents, the agent-based simulation is embedded into a heuristic search algorithm. The heuristic algorithm partially explores the solution space generated by the agent-based simulation. Because global information of the objective function value is used in the search algorithm, the schedule performance is improved. The proposed method shares the advantages from both agent-based modelling and mixed integer programing, achieving a better balance between the solution efficiency and the schedule performance. As a polynomial-time algorithm, the hybrid method is applicable to large-scale complex industrial scheduling problems. Its performance is demonstrated by comparing with agent-based modelling and mixed integer programing in two case studies, including a complex one from the Dow Chemical Company.

14/03556 Hybrid particle swarm optimization algorithm and its application in nuclear engineering

Liu, C. Y. *et al. Annals of Nuclear Energy*, 2014, 64, 276–286.
A hybrid particle swarm optimization (HPSO) algorithm with a feasibility-based rule for solving constrained optimization problems has been developed in this research. Firstly, the global optimal solution zone can be obtained through particle swarm optimization process, and then the refined search of the global optimal solution will be achieved through the modified Nelder–Mead simplex algorithm. Simulations based on two well-studied benchmark problems demonstrate the proposed algorithm will be an efficient alternative to solving constrained optimization problems. The vertical electrical heating pressurizer is one of the key components in reactor coolant system. The mathematical model of pressurizer has been established in steady state. The optimization design of pressurizer weight has been carried out through the HPSO algorithm. The results show the pressurizer weight can be reduced by 16.92%. The thermal efficiencies of conventional pressurized water reactor (PWR) nuclear power plants are about 31–35% so far, which are much lower than fossil fuelled plants based in a steam cycle as PWR. The thermal equilibrium mathematic model for nuclear power plant secondary loop has been established. An optimization case study has been conducted to improve the efficiency of the nuclear power plant with the proposed algorithm. The results show the thermal efficiency is improved by 0.5%.

14/03557 Improved hydrodynamic equations for the accurate prediction of diffusivities in supercritical carbon dioxide

Vaz, R. V. *et al. Fluid Phase Equilibria*, 2013, 360, 401–415.
The tracer diffusion coefficients are fundamental quantities in simulation and design. Due to the increasing interest in biorefinery and sustainability in general, green solvents and processes, like carbon dioxide and supercritical fluid extraction, are attracting relevance in both chemistry and chemical engineering research and development. In this work, tracer diffusion coefficients at infinite dilution are considered to propose reliable models for their pure estimation. Four predictive hydrodynamic models were proposed on the basis of modifications introduced in the original expressions of Wilke–Chang, Scheibel, Lusis–Ratcliff and Tyn–Calus. The modified equations provide reliable results with average absolute errors between 7.86% and 8.56%, and inferior dispersion around the averages. On the contrary, the original correlations taken from the literature achieve errors between 11.89% and 27.25%, along with higher scattering of results. Furthermore, the new expressions offer average errors between 0.47% and 0.53%, while the original ones provide systematic overestimations between 2.95% and 27.23%. In the whole, the new expressions proposed in this work are equally able to predict accurately tracer diffusion coefficients of any solutes in supercritical carbon dioxide.

14/03558 Individual decisions and system development – integrating modelling approaches for the heating market

Bauermann, K. *et al. Applied Energy*, 2014, 116, 149–158.
Improvements in the building stock insulation and the replacement of heating systems will have to take place within the coming decades in order to lower heat demand and the associated carbon emissions of the building sector. The current study presents an integrated, iterative modelling approach to determine the development of the heating market. A system model captures the fundamental influencing factors on the investment decision while a logistic decision model describes in detail the building owners' behaviour, taking into account the heterogeneous building stock and possible non-economic factors influencing heating system choice. In the application case, the potentials for different heating technologies are investigated under three different economic scenarios for the German heating market until 2050. The heating market with house owners as the main actors is relatively sluggish, thus political targets are likely to fail. The impact of the heat pump induced electricity demand on the power market remains low. In order to achieve the ambitious heating market targets in Germany further efforts are necessary. In particular the potentials of the existing building stock need to be taped more efficiently.

14/03559 Investigation of the shock wave propagation characteristics and cavitation effects of underwater explosion near boundaries

Wang, G. *et al. Applied Ocean Research*, 2014, 46, 40–53.
The shock wave propagation characteristics of underwater explosion have been of great interest to researchers. While the physical processes during an underwater explosion near boundaries are extremely complex, which involve lots of complex issues such as the explosion, shock wave propagation, water–air or water–structure interaction, etc. After the underwater detonation of an explosive, the shock wave may approach two main types of boundaries: the free surface of the water and the fluid–structure interface. The presence of these boundaries will significantly affect the wave propagation phenomena, and lead to bulk cavitation near the free surface or the structure surface. This paper deals with the behaviour of shock wave propagation and cavitation from underwater explosion near different boundaries. A coupled numerical approach with combined Lagrangian and Eulerian methods is used to simulate the water–air interface and shock wave–structure interaction. A numerical model of free-field explosion in water is established, and the results have been compared with the published empirical formulas to verify the results of numerical solutions. The shock wave propagation characteristics from explosions in water near different boundaries are simulated and compared. In addition, the unsteady cavitations just near the free surface and the structure surface are described and captured. The water–air and water–structure interaction effects are examined. The results show that the free surface and structure surface boundaries have significant influence on the shock wave propagation characteristics.

14/03560 Lennard–Jones parameters for combustion and chemical kinetics modeling from full-dimensional intermolecular potentials

Jasper, A. W. and Miller, J. A. *Combustion and Flame*, 2014, 161, (1), 101–110.
Lennard–Jones parameters for use in combustion modelling, as transport parameters and in pressure-dependent rate-coefficient calculations as collision rate parameters, are calculated from accurate full-dimensional intermolecular potentials. Several first-principles theoretical methods are considered. In the simplest approach, the intermolecular potential is spherically averaged and used to determine Lennard–Jones parameters. This method works well for small species, but it is not suitable for larger species due to unphysical averaging over the repulsive wall. Another method considered is based on full-dimensional trajectory calculations of binary collisions. This method is found to be very accurate, predicting Lennard–Jones collision rates within $\sim$10% of those obtained via tabulated (experimentally based) Lennard–Jones parameters. Finally, a computationally efficient method is presented based on one-dimensional minimizations averaged over the colliding partners' relative orientations. This method is shown to be both accurate and efficient. The good accuracy of the latter two approaches is shown to be a result of their explicit treatment of anisotropy. The effects of finite temperature vibrations and multiple conformers are quantified and are shown to be small. The choice of potential energy surface has a somewhat larger effect, and strategies based both on efficient semi-empirical methods and on first-principles direct dynamics are considered. Overall, 75 systems are considered, including seven baths, targets as large as heptane, both molecules and radicals, and both hydrocarbons and oxygenates.

14/03561 Magnetohydrodynamic flows entering the region of a flow channel insert in a duct

Kim, C. N. *Fusion Engineering and Design*, 2014, 89, (1), 56–68.
In this study, three-dimensional developing liquid-metal (LM) magnetohydrodynamic (MHD) flows entering the region of the flow channel insert (FCI) under a uniform magnetic field are numerically analysed. The features of the LM MHD flows in a square duct near the leading

edge of the FCI are examined in terms of flow velocity, pressure, current, electric potential and Lorentz force. Because near the leading edge of the FCI the current moves obliquely in the inner flow region, the pressure gradient along the main flow direction near the slit of FCI's leading edge is smaller, yielding a region of velocity recirculation with lower electric potential therein. The interdependency of current, fluid velocity, pressure, electric potential gradient, and Lorentz force is examined in order to describe the electromagnetic features of the current flows.

14/03562 Near infrared reflectance spectroscopy (NIRS) for rapid determination of biochemical methane potential of plant biomass

Triolo, J. M. *et al. Applied Energy*, 2014, 116, 52–57.

Determination of biochemical methane potential (BMP) by fermentation tests is time-consuming and costly, and therefore not useful for operators of full-scale biogas digesters. A great advantage of Near infrared reflectance spectroscopy (NIRS) in determining BMP is the reduction in measurement time from at least 1 month for chemical determination to a couple of minutes for production of near infrared spectroscopy (NIRS) spectra. An innovative NIRS method that can be used as an alternative to current BMP tests was developed in this study. The authors tested the partial least squares (PLS) model for a rapid determination of BMP using NIRS by applying a series of pre-processing methods with caution. A total of 88 plant biomass samples of a wide variety were used for model prediction. The standard error of the best PLS model was 37 CH_4 NL kg^{-1} VS, where BMP of the test set was between 136.2 and 477.9 CH_4 NL kg^{-1} VS. Coefficient of determination (R^2) and residual prediction deviation were 0.84 and 2.49, respectively. This shows that the new NIRS model is moderately successful in application and could be an alternative modern tool to overcome the problems of current BMP methods.

14/03563 Noble gas, CFC and other geochemical evidence for the age and origin of the Bath thermal waters, UK

Edmunds, W. M. *et al. Applied Geochemistry*, 2014, 40, 155–163.

The English city of Bath is a World Heritage site and its thermal waters, the Roman baths and new spa development rely on undisturbed flow of the springs (45 °C). The current investigations provide an improved understanding of the residence times and flow regime as basis for the source protection. Trace gas indicators including the noble gases (helium, neon, argon, krypton and xenon) and chlorofluorocarbons (CFCs), together with a more comprehensive examination of chemical and stable isotope tracers are used to characterize the sources of the thermal water and any modern components. It is shown conclusively by the use of ^{39}Ar that the bulk of the thermal water has been in circulation within the Carboniferous Limestone for at least 1000 years. Other stable isotope and noble gas measurements confirm previous findings and strongly suggest recharge within the Holocene time period (i.e. the last 12 kyr). Measurements of dissolved ^{85}Kr and chlorofluorocarbons constrain previous indications from tritium that a small proportion (<5%) of the thermal water originates from modern leakage into the spring pipe passing through Mesozoic valley fill underlying Bath. This introduces small amounts of O_2 into the system, resulting in the Fe precipitation seen in the King's Spring. Silica geothermometry indicates that the water is likely to have reached a maximum temperature of between 69–99 °C, indicating a most probable maximum circulation depth of ~3 km, which is in line with recent geological models. The rise to the surface of the water is sufficiently indirect that a temperature loss of >20 °C is incurred. There is overwhelming evidence that the water has evolved within the Carboniferous Limestone formation, although the chemistry alone cannot pinpoint the geometry of the recharge area or circulation route. For a likely residence time of 1–12 kyr, volumetric calculations imply a large storage volume and circulation pathway if typical porosities of the limestone at depth are used, indicating that much of the Bath–Bristol basin must be involved in the water storage.

14/03564 Numerical modelling of 3D woven preform deformations

Green, S. D. *et al. Composite Structures*, 2014, 108, 747–756.

In order to accurately predict the performance of three-dimensional (3D) woven composites, it is necessary that realistic textile geometry is considered, since failure typically initiates at regions of high deformation or resin pockets. This paper presents the development of a finite element model based on the multi-chain digital element technique, as applied to simulate weaving and compaction of an orthogonal 3D woven composite. The model was reduced to the scale of the unit cell facilitating high fidelity results combined with relatively fast analysis times. The results of these simulations are compared with microcomputed tomography scans of a dry specimen of fabric subjected to *in situ* compaction. The model accurately depicted all of the key features of the fabric including yarn waviness and cross-sectional shapes as well as their development with compaction. A parametric study is presented to characterize the effect of the model inputs on the analysis speed and accuracy.

14/03565 Power distribution gradients in WWER type cores and fuel failure root causes

Mikuš, J. M. *Nuclear Engineering and Design*, 2014, 267, 207–217.

Neutron flux non-uniformity and gradients of neutron current resulting in corresponding power (fission rate) distribution changes can represent root causes of the fuel failure. Such situation can be expected in vicinity of some core heterogeneities and construction materials. Since needed data cannot be obtained from nuclear power plant (NPP), results of some benchmark type experiments performed on light water, zero-power research reactor LR-0 were used for investigation of the above phenomenon. Attention was focused on determination of the spatial power distribution changes in fuel assemblies (FAs): containing fuel rods (FRs) with Gd burnable absorber in WWER-440 and WWER-1000 type cores, neighbouring the core blanket and dummy steel assembly simulators on the periphery of the WWER-440 standard and low leakage type cores, respectively, neighbouring baffle in WWER-1000 type cores and neighbouring control rod (CR) in WWER-440 type cores, namely (a) power peak in axial power distribution in periphery FRs of the adjacent FAs near the area between CR fuel part and butt joint to the CR absorbing part and (b) decrease in radial power distribution in FRs near CR absorbing part. An overview of relevant experimental results from reactor LR-0 and some information concerning leaking FAs on NPP Temelín are presented. Obtained data can be used for code validation and subsequently for the fuel failure occurrence investigation.

14/03566 Prediction of livestock manure and mixture higher heating value based on fundamental analysis

Choi, H. L. *et al. Fuel*, 2014, 116, 772–780.

The on-going availability of livestock waste presents an opportunity for its utilization as renewable energy resource through biological or thermochemical conversion. However, the conversion efficiency and the potential energy content of livestock waste needs to be estimated in order to design such a renewable energy production system. To address this, eight types of livestock waste were collected from each of 12 commercial farms from April to May 2009. The higher heating value (HHV), which represents the actual energy content, along with characteristics of livestock waste was determined. Moreover, equations for estimating HHV from proximate, ultimate, and chemical analysis were established by regression analysis. The developed equations were then validated using additional livestock waste data. The HHV of livestock waste was found to be in the range from 11.92 to 19.44 MJ/kg dry matter. The equation, HHV = 0.1970VM + 0.3955 represents the best-fit equations derived from proximate analysis with an average absolute error (AAE) value of 9.17%. The equation, HHV = 0.1865CH + 0.2671PR + 0.2141F – 0.2151 is best-fit equation derived from chemical analysis with an AAE value of 5.31%. The equation derived in this study, HHV = 0.3198C + 0.0803O + 0.4704N – 1.4502S + 0.9364, was compared with 10 recently published correlations based on ultimate analysis and showed better accuracy by having the lowest AAE values of 8.57%. All developed equations can be used to estimate HHV of various livestock waste with the exception of swine manure. The main reason for this limitation arises from the unique characteristics of pig manure in comparison to other livestock waste found in this study.

14/03567 Quantitative determination of pulp and paper industry emissions and associated odor intensity in methyl mercaptan equivalent using electronic nose

Deshmukh, S. *et al. Atmospheric Environment*, 2014, 82, 401–409.

The obnoxious odours generated from pulp and paper industries have been the cause of nuisance since the instigation of these industries. The objective of the study was to develop a metal oxide sensor-based electronic nose for rapid measurement of odorant concentration and associated odour intensity of major reduced sulfur compounds emitted from different sources of these pulp and paper mills. The gas samples collected from the surroundings of major source points of industry were exposed to sensor array of the electronic nose and the change in voltage was measured and taken to PC through data acquisition cards. The same sets of samples were also tested with gas chromatography (GC). The results of electronic nose and GC–flame photometric detector were correlated using response surface methodology to know the odorant concentration. The model fed with unknown industrial samples had more than 95% prediction capability. To determine odour intensity by electronic nose firstly a collective index was generated using singular value decomposition-based two-norm method (e-nose index) proportional to the sensors response relative to reference gas, methyl mercaptan. Secondly the e-nose index was associated with human expert evaluations. The training of the electronic nose enabled it to predict odorant concentration found at the industrial site and associated odour intensity in methyl mercaptan equivalent. The overall

results of the experiments carried out suggest the potential of electronic nose as a device for on- or off-line measurement of odorant concentration and odour intensity.

14/03568 Relationship between latent heat of sea spray and uncertainty of a meteorological field

Saruwatari, A. and Abe, N. *Applied Ocean Research*, 2014, 44, 102–111.

A surf zone with large breaking waves produces more spray than do offshore regions. Latent heat of spray evaporation causes changes in the surrounding temperature and wind velocity, resulting in further alterations in temperature, wind velocity and heat flux. Spray in a surf zone with large breaking waves may have non-ignorable effect on determination of a local meteorological field because of this interconnected relationship as well as its higher population than in the open ocean. In this study, the effects of the spray's latent heat on a meteorological field were investigated. The authors propose a method for estimating the latent heat of spray vaporization over the ocean. The method was applied to a meso-scale meteorological model to perform numerical experiments with consideration of heat flux by spray. Although the contribution of heat flux on the ocean was as small as 2.5%, fluctuations of air temperature and wind velocity increased over time due to the effects of spray. The fluctuations are thought to cause uncertainty in weather prediction. Numerical experiments with spray provided predictions of air temperature and wind velocity near a coast line that were consistent with observational data, especially when the population of spray droplets increased by two orders of magnitude as is often observed in a coastal area.

14/03569 Rethinking solar resource assessments in the context of global dimming and brightening

Müller, B. *et al. Solar Energy*, 2014, 99, 272–282.

Solar resource assessments use solar radiation data from past observations to estimate the average annual solar radiation over the expected lifetime for a solar energy system. However, solar radiation at the Earth's surface is not stable over time but undergoes significant long-term variations often referred to as global dimming and brightening. This study analyses the effect of these long-term trends on solar resource assessments. Based on long-term measurement records in Germany, it is found that the additional uncertainty of solar resource assessments caused by long-term trends in solar radiation is about 3% on the horizontal plane and even higher for tilted or tracked planes. These additional uncertainties are not included in most uncertainty calculations for solar resource assessments up to now. Furthermore, for the measurement stations analysed, the current irradiance level is about 5% above the long-term average of the years 1951–2010. Since the direction of future trends in solar radiation is not known, different possibilities to estimate the future solar resource are compared. In view of long-term trends that could extend beyond the period of past observations and beyond the projected lifetime of a solar energy application, a paradigm shift is proposed: instead of using the longest possible period to calculate an average value, only the 10 most recent years should be used as the estimator for future solar irradiance.

14/03570 Rheology of mineral oil-SiO_2 nanofluids at high pressure and high temperatures

Anoop, K. *et al. International Journal of Thermal Sciences*, 2014, 77, 108–115.

Nanofluids, engineered colloidal suspensions of nano-sized particles (<100 nm) dispersed in a base fluid, have shown potential for use as industrial cooling fluids due to their enhanced heat transfer capabilities. Many industrial applications often involve heat transfer fluids at pressures and temperatures above average atmospheric condition. Understanding the rheological characteristics of nanofluids is necessary for implementing them in these extreme conditions. Even though the effect of temperature on the viscosity of nanofluids at atmospheric pressure has been well studied, viscosity measurements of nanofluids at elevated pressures and temperatures have not yet been investigated. This work investigates the rheological characteristics of mineral oil-based nanofluids at high pressure and high temperature (HPHT). The nanofluids used in this work were prepared by mechanically dispersing commercially available SiO_2 nanoparticles (~20 nm) in a highly refined paraffinic mineral oil (Therm Z-32, QALCO QATAR), which has wide applications in industrial heat exchangers. Mineral oil and nanofluids, with two volume concentrations of 1% and 2%, are studied in this work. The rheological characteristics of the base fluid and nanofluids are measured using an HPHT viscometer. During experimentation, viscosity values of the nanofluids are measured at pressures of 100 kPa and 42 MPa, with temperatures ranging from 25 to 140 °C, and at varying shear rates. The results show that the viscosity values of both nanofluids, as well as the base fluid, increased as the pressure increased. In addition, nanofluids exhibit non-Newtonian characteristics at elevated temperatures and pressures.

14/03571 Simple statistical model for complex probabilistic climate projections: overheating risk and extreme events

Patidar, S. *et al. Renewable Energy*, 2014, 61, 23–28.

Climate change could substantially impact the performance of the buildings in providing thermal comfort to occupants. Recently launched UK climate projections (UKCP09), indicate that all areas of the UK will get warmer in the future with the possibility of more frequent and severe extreme weather events such as heat waves. This study, as part of the Low Carbon Futures (LCF) project, explores the consequent risk of overheating and the vulnerability of a building to extreme events. A simple statistical model proposed by the LCF project elsewhere has been employed to emulate the outputs of the dynamic building simulator (ESP-r) which cannot feasibly be used itself with the available probabilistic climate database. The impact of climate change on the daily external and internal temperature profiles has been illustrated by means of three-dimensional plots over the entire overheating period (May to October) and over 3000 equally probable future climates. Frequency of extreme heat events in a changing climate and its impact on overheating issues for a virtual case study domestic house has been analysed. Results are presented relative to a baseline climate (1961–1990) for three future timelines (2030s, 2050s and 2080s) and three emission scenarios (low, medium and high).

14/03572 Spectral analysis of aeromagnetic data for geothermal investigation of Wikki Warm Spring, north-east Nigeria

Obande, G. E. *et al. Geothermics*, 2014, 50, 85–90.

Spectral analysis of residual magnetic anomalies from aeromagnetic data has been used to estimate the Curie point depth (CPD) in the Wikki Warm Spring area of north-eastern Nigeria which lies within the Upper Benue Trough. The CPD is that depth at which the dominant magnetic mineral in the crust passes from a ferromagnetic state to a paramagnetic state under the effect of increasing temperature. This, alongside the approximate Curie temperature for magnetite, was used to infer the thermal gradient and hence the average heat flow in the area which is found to indicate anomalous geothermal conditions. This study confirms indications of crustal thinning in the Upper Benue Trough and suggestions that abnormally hot material can be found beneath the trough at comparably shallow depths. The Wikki Warm Spring area has a great energy potential with an estimated average CPD of 8 km, an average geothermal gradient of 68 °C/km and very high heat flow values (an average of 170 mW/m^2). It has been shown that temperatures greater than 100 °C can be reached at depths of less than 2 km thus making the Wikki Warm Spring a promising area for exploration of geothermal resources.

14/03573 Study on harmonic emission of domestic equipment combined with different types of lighting

Gil-de-Castro, A. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 55, 116–127.

This paper presents the results of a set of measurements to study changes in harmonic emission from domestic equipment due to the introduction of energy-efficient lamps. During this study measurements have been performed of the emission from different combinations of domestic devices in combination with different kind of lamps. Those results are then compared with standards, with a mathematical aggregation model and with results from field experiments in order to give recommendations to different stakeholders. The measurements clearly show that the total emission depends on the lamps that are connected as a background. It is however not possible to draw the general conclusion that the introduction of compact fluorescent lamps (CFLs) and light-emitting diode (LED) lamps will result in an increase or decrease of emission. It is also concluded in this work that the International Electrotechnical Commission aggregation model does not give useful estimations of changes in emission from domestic installations due to the introduction of CFLs and LED lamps. The measurement results further indicate that emission levels at higher frequencies might increase due to the large-scale introduction of such lamps.

14/03574 The effect of weather forecast uncertainty on a predictive control concept for building systems operation

Petersen, S. and Bundgaard, K. W. *Applied Energy*, 2014, 116, 311–321.

This paper investigates the effects of weather forecast uncertainty on the performance of a concept for predictive control of building systems operation. The concept uses a computational physically based building model and weather forecasts to predict future heating or cooling requirement. This information enables the building systems to respond proactively to keep the operational temperature within the thermal comfort range with the minimum use of energy. The effect of weather forecast uncertainty was assessed using weather data from two different years in a temperate climate in the simulation of 24 building design scenarios. Despite the uncertainty in the weather forecasts, the

predictive control concept demonstrated a potential for energy savings and/or improvements in thermal indoor environment when compared to a conventional rule-based control.

14/03575 Thermal conductivity of ethylene glycol and water mixture based Fe_3O_4 nanofluid

Sundar, L. S. *et al. International Communications in Heat and Mass Transfer*, 2013, 49, 17–24.

Thermal conductivity of an ethylene glycol and water mixture-based Fe_3O_4 nanofluid has been investigated experimentally. Magnetic Fe_3O_4 nanoparticles were synthesized by a chemical co-precipitation method and the nanofluids were prepared by dispersing nanoparticles into different base fluids such as 20 : 80%, 40 : 60% and 60 : 40% by weight of the ethylene glycol and water mixture. Experiments were conducted in the temperature range from 20 to 60 °C and in the volume concentration range from 0.2% to 2.0%. Results indicate that the thermal conductivity increases with the increase of particle concentration and temperature. The thermal conductivity is enhanced by 46% at 2.0 vol.% of nanoparticles dispersed in 20 : 80% ethylene glycol and water mixture compared to other base fluids. The theoretical Hamilton–Crosser model failed to predict the thermal conductivity of the nanofluid with the effect of temperature. A new correlation is developed for the estimation of thermal conductivity of nanofluids based on the experimental data.

14/03576 Validation of a hydrodynamic model for a curved, multi-paddle wave tank

Gyongy, I. *et al. Applied Ocean Research*, 2014, 44, 39–52.

Obtaining a hydrodynamic model for a wave tank has many benefits, from allowing the useable test zone to be identified, to helping with the tuning of the wave-maker controllers. This paper explores a first-order, boundary element method that has been previously proposed for modelling wave tanks, applying the method to a tank with a unique, curved geometry. In a series of experiments, the model is shown to provide a good representation of the wave profile across the tank. Inherent limitations in the method are also identified: in the case when only a single paddle is moved, significant, unmodelled second-order spurious waves are found to emerge. Moreover, the representation of the wave absorbers by a simple, partially reflecting surface does not adequately reproduce the measured spatial variation in the reflection coefficient.

Fuel cell technology

14/03577 A new alkali-resistant Ni/Al_2O_3-MSU-1 core–shell catalyst for methane steam reforming in a direct internal reforming molten carbonate fuel cell

Zhang, J. *et al. Journal of Power Sources*, 2014, 246, 74–83.

An alkali-resistant catalyst for direct internal reforming molten carbonate fuel cell (DIR-MCFC) is prepared by growing a thin shell of mesoporous MSU-1 membrane on Ni/Al_2O_3 catalyst beads. The MSU-1 shell is obtained by first depositing a monolayer of colloidal silicalite-1 (Sil-1) on the catalyst bead as linkers and then using NaF stored in the beads to catalyse the growth of the MSU-1 layer. The resulting core–shell catalysts display excellent alkali-resistance and deliver stable methane conversion and hydrogen yield in an out-of-cell test simulating the operating conditions of an operating DIR-MCFC. Higher conversion and yield (i.e. up to over 70%) are obtained from the new core–shell catalyst with MSU-1 shell compared to the catalyst with microporous Sil-1 shell. A mathematical model of the reaction and poisoning of the core–shell catalyst is used to predict the optimum shell thickness for its reliable use in a DIR-MCFC.

14/03578 Conductive particles embedded carbon composite bipolar plates for proton exchange membrane fuel cells

Lim, J. W. *et al. Composite Structures*, 2014, 108, 757–766.

Proton exchange membrane (PEM) fuel cell systems are environmentally friendly power sources that have many potential applications. Although carbon fibre composite bipolar plates have high strength and stiffness with good corrosion resistance in an acid environment, they exhibit only a marginal electrical conductivity, which compromises the efficiency of PEM fuel cells. In this work, electrically conductive particles (graphite powder and carbon black) are sprayed onto carbon–epoxy composite prepregs of a bipolar plate to decrease the electrical resistivity of the bipolar plate. The electrical resistance and mechanical properties are measured using conventional test methods. In addition, a unit cell performance assessment is conducted with the developed carbon composite bipolar plates and compared with that of the conventional bipolar plate.

14/03579 Effect of presence of cellulose in the freshwater sediment on the performance of sediment microbial fuel cell

Sajana, T. K. *et al. Bioresource Technology*, 2014, 155, 84–90.

The performance of sediment microbial fuel cells (SMFCs) was evaluated in the presence of cellulose in the aquaculture pond sediment as 2% (w/w) in SMFC-2, 4% in SMFC-3 and without adding cellulose in SMFC-1. From aquaculture water, average chemical oxygen demand (COD) and total nitrogen (TN) removal efficiencies of $80.6 \pm 0.3\%$ and $83.0 \pm 0.01\%$ were obtained in SMFC-1, $88.2 \pm 0.5\%$ and $89.6 \pm 0.8\%$ in SMFC-2 and $83.1 \pm 0.3\%$ and $64.5 \pm 1.6\%$ in SMFC-3, respectively. During the complete experimental period, acetic acid was the only short chain fatty acid detected in all three SMFCs. Sediment organic matter removal in SMFC-1, SMFC-2 and SMFC-3 were 16%, 22% and 18.6%, respectively. SMFCs demonstrated effective cellulose degradation from aquaculture pond sediment and maintained the oxidized sediment top layer favourable for aquaculture.

14/03580 Influence of co-vapors on biogas filtration for fuel cells monitored with PTR-MS (proton transfer reaction-mass spectrometry)

Papurello, D. *et al. Fuel Processing Technology*, 2014, 118, 133–140.

Solid oxide fuel cells (SOFCs) fed by biogenic fuels are a key renewable energy technology. Fuel contaminants, and sulfur compounds in particular, can strongly decrease SOFC performance. For this reason, their accurate, high sensitivity, and rapid monitoring and the development of successful removal strategies are major challenges in SOFC research. In this work the removal efficiency of commercial activated carbon filters for biogas filtering upstream of an SOFC was investigated using a proton transfer reaction-mass spectrometry instrument (PTR-MS). In particular, the authors tested sulfur compounds by focusing on the effect of co-vapour adsorption (aromatic, carbonyl and chloro-compounds which are biogas pollutants) on filter performance. The results demonstrate the applicability of PTR-MS for investigating co-vapour effects which are of practical relevance for SOFC development.

14/03581 Light intensity affects the performance of photo microbial fuel cells with *Desmodesmus* sp. A8 as cathodic microorganism

Wu, Y.-c. *et al. Applied Energy*, 2014, 116, 86–90.

The performance of photomicrobial fuel cells (photo-MFCs) with *Desmodesmus* sp. A8 as cathodic microorganism under different light intensities (0, 1500, 2000, 2500, 3000, 3500 lx) was investigated. The results showed that illumination enhanced the output of the photo-MFC three-fold. When light intensity was increased from 0 to 1500 lx, cathode resistance decreased from 3152.0 to 136.7 Ω while anode resistance decreased from 13.9 to 11.3 Ω. In addition, the cathode potential increased from −0.44 to −0.33 V (vs Ag/AgCl) and reached a plateau as the light intensity was increased from 1500 to 3500 lx. Accompanied with the potential change, dissolved oxygen (DO) within the cathode biofilm increased to 13.2 mg L^{-1} under light intensity of 3500 lx and dropped to 7.5 mg L^{-1} at 1500 lx. This work demonstrated that light intensity profoundly impacted the performance of photo-MFC with *Desmodesmus* sp. A8 through changing the DO.

14/03582 Nanomodification of the electrodes in microbial fuel cell: impact of nanoparticle density on electricity production and microbial community

AlZahra'a Alatraktchi, F. *et al. Applied Energy*, 2014, 116, 216–222.

The nano-decoration of electrode with nanoparticles is one effective way to enhance power output of microbial fuel cells (MFCs). However, the amount of nanoparticles used for decoration has not been optimized yet, and how it affects the microbial community is still unknown. In this study, different densities of gold (Au) nanoparticles were sputtered on carbon paper as electrodes of MFCs. The results show that power generation increased with Au nanoparticle density on the electrodes. The highest power density was obtained by depositing carbon paper with an Au thickness of 50 and 100 nm on each side, respectively, which was 1.22–1.88 times higher than that obtained with plain carbon paper electrode (control). Furthermore, the Coulombic efficiency was increased with the Au density. Consequently, the maximum lag time before stable power generation was shortened by 1.22 times the lag time of the control. Different densities of Au nanoparticles also resulted in different microbial communities on the anode. More diverse bacterial communities were found with higher Au nanoparticle densities. These results provide new dimensions in understanding electrode modification with nanoparticles in MFC systems.

14/03583 Numerical simulations of water droplet dynamics in hydrogen fuel cell gas channel

Kim, H.-Y. *et al. Journal of Power Sources*, 2014, 246, 679–695.

The droplet dynamics in the cathode gas flow channel of a hydrogen fuel cell has been numerically investigated to obtain ideas for designing a flow channel to effectively prevent flooding. Three-dimensional two-

phase flow simulations employing the volume of fluid method have been performed. Liquid droplets emerging from two adjacent pores at the hydrophobic bottom wall are subjected to airflow in the bulk of the gas flow channel. The effects of various parameters (pore distance, locations, sidewall contact angle, and airflow rate) on the liquid water removal from the gas channel have been investigated in terms of liquid water saturation, coverage of liquid water on the gas diffusion layer (GDL) surface, and change in the pressure drop in the channel. The numerical results show that the coalescence of two adjacent droplets enhances the water removal as compared to two separate, small droplets. It is also observed that droplets generated near the hydrophilic sidewall can be attached to the upper corner of the channel walls, which prevents the liquid water from covering the GDL surface, whereas the hydrophobic sidewall may cause clogging of the gas channel with liquid water at a low airflow rate.

14/03584 Numerical study on thermal stresses of a planar solid oxide fuel cell
Fan, P. *et al. International Journal of Thermal Sciences*, 2014, 77, 1–10.
A three-dimensional (3D) finite element model consists of positive electrode–electrolyte–negative electrode (PEN) and metallic interconnect assembly is constructed by using commercial finite element software Abaqus. With the simulated temperature profile in the planar solid oxide fuel cell (SOFC), the finite element method is employed to calculate the thermal stress distribution in a planar SOFC. The effects of temperature profile, electrodes and electrolyte thickness, and coefficients of thermal expansion (CTEs) mismatch between components are characterized. The value and distribution of thermal stress are the functions of the applied materials CTEs, applied temperature profiles and thickness of anode and electrolyte. The calculated results can be applied as the guide for SOFC materials selection and SOFC structure design. The anode is subjected to large tensile stresses and the electrolyte is subjected to large compressive stresses during the first cooling from the sintering temperature. The chemical reduction of NiO to Ni in the porous anode lowers the absolute stress level in the PEN structure by 20%. The large tensile stresses in the anode and the large compressive stresses in the electrolyte relax partly when the SOFC operates at high temperature. Cracks could probably appear in the anode structure when the PEN structure is cooling to room temperature after the sintering.

14/03585 Performance investigation of linear and nonlinear controls for a fuel cell/supercapacitor hybrid power plant
Thounthong, P. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 54, 454–464.
In this paper, linear proportional–integral (PI) and non-linear flatness-based controllers for dc link stabilization for fuel cell/supercapacitor hybrid power plants are compared. For high power applications, four-phase parallel boost converters are implemented with a switching interleaving technique for a fuel cell (FC) converter, and four-phase parallel bidirectional converters are implemented with a switching interleaving technique for a supercapacitor converter in the laboratory. As controls, mathematical models (reduced-order models) of the FC converter and the supercapacitor converter are given. The prototype small-scale power plant studied is composed of a proton exchange membrane fuel cell system (the Nexa Ballard FC power generator: 1.2 kW, 46 A) and a supercapacitor module (100 F, 32 V, based on Maxwell Technologies Co.). Simulation (by Matlab/Simulink) and experimental results demonstrate that the non-linear differential flatness-based control provides improved dc bus stabilization relative to a classical linear PI control method.

14/03586 The effect of overpotentials on the transient response of the 300 W SOFC cell stack voltage
Komatsu, Y. *et al. Applied Energy*, 2014, 115, 352–359.
This paper presents the results of an experimental investigation of transient characterizations of 300 W planar type solid oxide fuel cell (SOFC) cell stack during load change. It indicates the transient characterization obtained during a ramped electric current with a current-based fuel control (CBFC) strategy. The fuel utilization factor is chosen for a reference of the CBFC strategy and is kept constant to the ramping electric current. The fuel utilization factor can be described as a ratio of consumed fuel (expressed as a function with an applied electric current) to supplied fuel. For the simplification of discussion, hydrogen was used as fuel by mixing it with nitrogen in order to satisfy the constant gas residential time in all cases and instances. The transient response of the cell voltage obtained under several thermal conditions was shown for discussion. The effect of overpotentials, associated with the cell's operating temperature, on the transient response of the cell voltage is primarily discussed. The paper indicates that reducing the fuel flow rate, namely, setting a higher set-point for the fuel utilization factor, may decrease the open-circuit voltage, increase concentration polarization and finally degrade cell performance. This paper also pointed out the importance of operating temperature management on both improving the steady-state cell performance and eliminating the negative effect of the overpotentials that appear on the transient response of the cell voltage.

15 ENVIRONMENT

Pollution, health protection, applications

14/03587 A modelling study of the impact on air quality and health due to the emissions from E85 and petrol fuelled cars in Sweden
Fridell, E. *et al. Atmospheric Environment*, 2014, 82, 1–8.
Alternative fuels are becoming more and more important for road traffic and one fuel that has been used for several years is ethanol (E85). The main discussion points regarding the environmental performance for ethanol as a fuel are related to the production. However, there are also some notable differences in the emissions between E85 and petrol-fuelled vehicles. This relates to some extent to the emissions of nitrogen oxides (NO_x) and particulate matter (PM) but mainly to the composition of the emitted organic compounds. In the present study two fuel scenarios for passenger cars are investigated for the Västra Götaland region in Sweden; one where the cars with Otto engines run on petrol and one where they run on E85. Two emission scenarios for 2020 are constructed for the whole Europe and coupled dispersion-chemistry modelling is applied to obtain the population exposure to key pollutants. The differences obtained from the modelling show decreased levels of NO_x, ozone and benzene with E85 and increased levels of acetaldehyde in the Västra Götaland region. For the latter the increase may be up to 80%, while NO_x and ozone show decreases of up to a few per cent and a few tenths of per cent, respectively. Exposure to the different air pollutants is calculated as population-weighted concentrations. The health risk assessment, using the calculated exposure and published exposure–response functions for the relevant pollutants, shows decreased health risks in the E85 scenario relative the all-petrol scenario, due to the decreased NO_x exposure, correlated with both preterm deaths and asthma. However, NO_x (and NO_2) may partly be indicators of unmeasured causal exhaust components in the epidemiological studies and thus the exposure–response functions for these may not be applicable in the present case where there is a difference in NO_x exposure but not a proportional difference in exposure to other exhaust components normally associated with NO_x. Smaller effects are expected from the changes in ozone, acetaldehyde, $PM_{2.5}$ and benzene exposure. The overall difference is about 1.6 preterm deaths per year for the Västra Götaland region, with lower values for the E85 scenario, when the uncertain differences due to the differences in NO_x exposure are not considered.

14/03588 An international comparative analysis of public acceptance of nuclear energy
Kim, Y. *et al. Energy Policy*, 2014, 66, 475–483.
Public acceptance of nuclear power is a crucial factor for governmental establishment of a nuclear energy programme. Therefore, it is important to understand the determinants of public acceptance of nuclear power. This study examines the effects of knowledge, trust, risk and benefit related factors on public acceptance of nuclear power across 19 countries. This study considers three levels of public acceptance – strongly accept, reluctantly accept and oppose – and classify countries into four groups according to the ratio of those three levels of public acceptance. The results indicate that knowledge of nuclear inspection is more effective than trust in inspection authorities in creating stronger public acceptance among people in the countries with a high level of reluctant acceptance and a low level of strong acceptance, while trust in inspection authorities is more important than knowledge of nuclear inspection for the selection between opposition and reluctant acceptance in countries with a low level of reluctant acceptance and a high level of strong acceptance. Without grouping the countries, it was found that trust in inspection authorities is crucial for the decision between opposition and reluctant acceptance. Additionally, the generation of electricity has the most positive effect on public acceptance of nuclear power.

14/03589 An investigation on unintended reactor trip events in terms of human error hazards of Korean nuclear power plants
Kim, S. K. *et al. Annals of Nuclear Energy*, 2014, 65, 223–231.

A new approach for finding the hazards of human errors, and not just their causes in the nuclear industry is currently required. This is because finding causes of human errors is really impossible owing to the multiplicity of causes in each case. Thus, this study aims at identifying the relationships among human error hazards and determining the strategies for preventing human error events by means of a reanalysis of the reactor trip events in Korean nuclear power plants. The authors investigated human errors to find latent factors such as decisions and conditions in all of the unintended reactor trip events during the last dozen years. In this study, the HFACS (Human Factors Analysis and Classification System) was applied. HFACS is a commonly tool for investigating human contributions to aviation accidents under a widespread evaluation scheme. In this study, countermeasures against human errors were determined through dealing with latent factors such as preconditions of unsafe acts, unsafe supervisions, and organizational influences. The countermeasures were drawn by analysing associations between these latent factors statistically. However, a limitation of this study still remains. The limitation is related with the completion of HFACS classifications which consist of four hierarchical levels. Generally, the fact that causes and routes of human errors are very complex and latent makes these types of limitations. To cope with such limitations, domain specific classifications are the main key. In particular, nature terminology should be set by domain experts. For future researches, the HFACS frameworks and classifications of this study should be validated through more field studies.

14/03590 Chemical supply chain modeling for analysis of homeland security events

Ehlen, M. A. *et al. Computers & Chemical Engineering*, 2014, 60, 102–111.

The potential impacts of human-made and natural disasters on chemical plants, complexes, and supply chains are of great importance to homeland security. To be able to estimate these impacts, the authors developed an agent-based chemical supply chain model that includes: chemical plants with enterprise operations such as purchasing, production scheduling, and inventories; merchant chemical markets, and multi-modal chemical shipments. Large-scale simulations of chemical-plant activities and supply chain interactions, running on desktop computers, are used to estimate the scope and duration of disruptive-event impacts, and overall system resilience, based on the extent to which individual chemical plants can adjust their internal operations (e.g. production mixes and levels) versus their external interactions (market sales and purchases, and transportation routes and modes). To illustrate how the model estimates the impacts of a hurricane disruption, a simple example model centred on 1,4-butanediol is presented.

14/03591 Comparative analysis of key socio-economic and environmental impacts of smallholder and plantation based jatropha biofuel production systems in Tanzania

van Eijck, J. *et al. Biomass and Bioenergy*, 2014, 61, 25–45.

Two jatropha business models are compared on seven key sustainability areas of concern, which are operationalized into various quantitative and qualitative indicators. The assessment is based on two Tanzanian real-life cases, a wide range of primary and secondary sources are used. Results indicate that both the decentralized smallholder model and the centralized plantation model can lead to positive socio-economic and environmental impacts, but substantial differences are also apparent. The smallholder model scores better on land rights, greenhouse gas balance and biodiversity and it reaches more people, whereas the plantation model creates more employment and higher (local prosperity) benefits for smaller numbers of people, and could lead to higher yields. Negative impacts of the smallholder model are minimal, whereas the plantation model could lead to decreased food security, loss of land rights and biodiversity. This could permanently affect the livelihood situation of the local population, but this is not inevitable as there is considerable scope for implementing mitigating policies. The way in which a particular model is implemented in practice, its management and company values, can have a major influence. However, the biggest hurdle towards achieving sustained positive societal impacts in both models is their marginal profitability at current yields, costs and prices. Still, these results are highly sensitive to uncertain yields and oil prices. Better outcomes in the future are therefore not foreclosed. A reliable sustainability assessment requires many location-specific and operational company data. More quantitative indicators are ideally required to improve assessment of social impacts and effects on environment.

14/03592 Estimating the net societal value of distributed household PV systems

Oliva H., S. *et al. Solar Energy*, 2014, 100, 9–22.

This paper presents a methodology for estimating the net marginal societal value of distributed residential PV systems within the Australian national electricity market. It includes the potential direct marginal energy value of photovoltaics (PV) including avoided losses, and marginal environmental value with respect to regional air pollutants and greenhouse gas emissions. This methodology is then applied for the example of 61 domestic rooftop PV systems located in Sydney. Results highlight that residential PV systems would seem to offer net societal benefits under reasonable assumptions of their energy and environmental values including the social cost of carbon, and given social discount rates. Much depends, however, on the assumed level of the social cost of carbon and the system performance including issues of orientation, maintenance and shading. While such evaluations of societal value are challenging, they have an important policy role in better aligning private incentives for and against residential PV deployment with the societal benefits that such deployment can bring.

14/03593 Fog-water collection for community use

Fessehaye, M. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 52–62.

Fog is a potential source of water that could be exploited using the innovative technology of fog collection. Naturally, the potential of fog has proven its significance in cloud forests that are thriving from fog interception. Historically, the remains of artificial structures in different countries prove that fog has been collected as an alternative and/or supplementary water source. In the beginning of the nineteenth century, fog collection was investigated as a potential natural resource. After the mid-1980s, following success in Chile, fog-water collection commenced in a number of developing countries. Most of these countries are located in arid and semi-arid regions with topographic and climatic conditions that favour fog-water collection. This paper reviews the technology of fog collection with initial background information on natural fog collection and its historical development. It reviews the climatic and topographic features that dictate fog formation (mainly advection and orographic) and the innovative technology to collect it, focusing on the amount collected, the quality of fog water, and the impact of the technology on the livelihoods of beneficiary communities. By and large, the technology described is simple, cost-effective and energy-free. However, fog-water collection has disadvantages in that it is seasonal, localized and the technology needs continual maintenance. Based on the experience in several countries, the sustainability of the technology could be guaranteed if technical, economic, social, and management factors are addressed during its planning and implementation.

14/03594 Geochemical and mineralogical investigation of uranium in multi-element contaminated, organic-rich subsurface sediment

Qafoku, N. P. *et al. Applied Geochemistry*, 2014, 42, 77–85.

Subsurface regions of alluvial sediments characterized by an abundance of refractory or lignitic organic carbon compounds and reduced Fe and S bearing minerals, which are referred to as naturally reduced zones (NRZ), are present at the Integrated Field Research Challenge site in Rifle, Colorado, USA (a former U mill site), and other contaminated subsurface sites. A study was conducted to demonstrate that the NRZ contains a variety of contaminants and unique minerals and potential contaminant hosts, investigate micron-scale spatial association of U with other co-contaminants, and determine solid phase-bounded U valence state and phase identity. The NRZ sediment had significant solid phase concentrations of U and other co-contaminants suggesting competing sorption reactions and complex temporal variations in dissolved contaminant concentrations in response to transient redox conditions, compared to single contaminant systems. The NRZ sediment had a remarkable assortment of potential contaminant hosts, such as Fe oxides, siderite, Fe(II) bearing clays, rare solids such as ZnS framboids and CuSe, and, potentially, chemically complex sulfides. Micron-scale inspections of the solid phase showed that U was spatially associated with other co-contaminants. High concentration, multi-contaminant, micron size (*ca.* 5–30 μm) areas of mainly U(IV) (53–100%) which occurred as biogenic UO_2 (82%), or biomass – bound monomeric U(IV) (18%), were discovered within the sediment matrix confirming that biotically induced reduction and subsequent sequestration of contaminant U(VI) via natural attenuation occurred in this NRZ. A combination of assorted solid phase species and an abundance of redox-sensitive constituents may slow U(IV) oxidation rates, effectively enhancing the stability of U(IV) sequestered via natural attenuation, impeding rapid U flushing, and turning NRZs into sinks and long-term, slow-release sources of U contamination to groundwater.

14/03595 Global environmental transfer of ^{129}I

Sunny, F. *et al. Annals of Nuclear Energy*, 2014, 65, 320–324.

Iodine-129 is released to the environment via natural production due to cosmic interaction in the upper atmosphere; past nuclear weapon tests and routine releases from nuclear power plants (NPP) and fuel reprocessing plants (FRP). In this study, a compartmental model is used to estimate the transfer of ^{129}I through various environmental segments such as ocean atmosphere, land atmosphere, terrestrial

biosphere, ocean mixed layer, surface soil, deep ocean, ocean sediment, shallow subsurface soil and deep subsurface soil due to its release in any one or more compartments. Due to NPP and FRP releases into the land atmosphere for a period of 1000 years, the highest inventory of ^{129}I is observed in the surface soil up to a period of 3000 years; afterwards the deep ocean shows the highest inventory. The lowest inventory is found in the ocean sediment up to a period of 200 years; followed by the ocean atmosphere up to a period of 1250 years; afterwards the land atmosphere shows the lowest inventory. The maximum annual effective dose to the world population due to releases of ^{129}I from NPP and FRP for a period of 100 years is estimated as 4.14×10^{-6} mSv/year. If the release period is 1000 years, the annual effective dose increases to 1.05×10^{-5} mSv/year and for an infinite period of release, it is estimated as 1.5×10^{-4} mSv/year. The model results are verified by comparing the effective dose per TBq release of ^{129}I at different time periods with those reported by different international agencies and good matching is observed among the values.

14/03596 How does individual low-carbon consumption behavior occur? – an analysis based on attitude process

Chen, H. *et al. Applied Energy*, 2014, 116, 376–386.

Low-carbon consumption is an inevitable choice in the development of a low-carbon economy. Based on analysis of the attitude-formation process, a study of the individual key consumption conditions from the cognitive process, to the affective process and to final behavioural choice tendency was carried out. A new theoretical model of the realization process of low-carbon consumption was constructed and an empirical study followed. The results show that the functional consumption value and the economical consumption value have significant influences on low-carbon consumption cognition. The social consumption value significantly influences the preference for low-carbon consumption preferences to others and low-carbon consumption behavioural tendency. Environmental cognition and cognition of low-carbon consumption significance impact low-carbon consumption preference to selves significantly, and low-carbon consumption preference to others has a significant influence on low-carbon consumption behavioural tendency. Environmental cognition and low-carbon consumption preference to selves negatively impact individual consciousness consumption behaviour, while environmental cognition, cognition of low-carbon consumption, low-carbon consumption preference to others and low-carbon consumption behavioural tendency positively impact social consciousness consumption behaviour. The negative moderated effects of social consumption culture on low-carbon consumption preference to selves and low-carbon consumption behavioural tendency, low-carbon consumption behavioural tendency and individual consciousness consumption behaviour are significant. After discussion of the research results, strategies to promote individual low-carbon consumption behaviour are proposed.

14/03597 Introducing carbon taxes in South Africa

Alton, T. *et al. Applied Energy*, 2014, 116, 344–354.

South Africa is considering introducing a carbon tax to reduce greenhouse gas emissions. Following a discussion of the motivations for considering a carbon tax, the authors evaluate potential impacts using a dynamic economy-wide model linked to an energy sector model including a detailed evaluation of border carbon adjustments. Results indicate that a phased-in carbon tax of US$30 per ton of CO_2 can achieve national emissions reductions targets set for 2025. Relative to a baseline with free disposal of CO_2, constant world prices and no change in trading partner behaviour, the preferred tax scenario reduces national welfare and employment by about 1.2% and 0.6%, respectively. However, if trading partners unilaterally impose a carbon consumption tax on South African exports, then welfare/employment losses exceed those from a domestic carbon tax. South Africa can lessen welfare/employment losses by introducing its own border carbon adjustments. The mode for recycling carbon tax revenues strongly influences distributional outcomes, with trade-offs between growth and equity.

14/03598 Materials composition or energy characteristic – what is more important in environmental life cycle of buildings?

Pajchrowski, G. *et al. Building and Environment*, 2014, 72, 15–27.

The energy requirement of buildings is directly related to the technology of their construction and the type and amount of used building materials. The higher the cost of purchasing materials, especially insulation materials, the lower the expected costs of use are, which is connected with lower energy losses. The dilemma between the increased building costs and the higher costs of use is rather common, and the investors usually make their decisions based on the economic criteria. However, in the era of sustainable building and a tendency of introducing environmental factors into the decision-making processes, the environmental costs related to the individual decision-making scenarios have become a more frequent additional criterion accompanying the process of resolving of such a dilemma. Within the scope of this paper, the results of a comparative environmental life cycle assessment (LCA) of four functionally equivalent buildings with different material structure, construction technology and energy standards have been presented. The main goal of the analyses has been providing the answer to the question, what is the key element, from the environmental point of view, in the life cycle of buildings and is it a common element regardless of the technology of construction and the energy standards. The analyses that have been carried out have confirmed the results obtained in other LCA studies, namely that the main source of negative environmental impact in the life cycle of buildings is the energy consumption in the long-term use of the buildings. However, these studies have also shown that this could be a critical aspect regardless of the building type (material structure, construction technology or energy standard). Nevertheless, perhaps the most crucial conclusion of the studies is that not only the amount of the used energy but also its type plays the key role. In the analyses that have been carried out, rather surprising results have been obtained, which showed that passive buildings – having nearly 3.6 times lower total energy requirement – turn out to perform poorer in stage 4 (use), which is mainly due to satisfying energy requirements entirely with electric energy as it was assumed in this theoretical case study. The obtained results can underlie a good starting point for a discussion about the simplifications of LCA studies performed for the buildings. The obtained results also showed that exclusion the following inventory elements should not cause the losses of crucial LCA information: transport of the building materials to building site, construction of the buildings, replacements and repairs (use), renovations and maintenance (use), demolition, transport of building waste, final disposal of the waste. The exclusion of these inventory elements let to preserve 90% of the environmental impact by reducing the inventory data intensity by 75%. The similar results were obtained regardless the material composition and energy characteristic of the buildings.

14/03599 Population growth in polluting industrialization

Constant, K. *et al. Resource and Energy Economics*, 2014, 36, (1), 229–247.

Recently, many contributions have focused on the relationship between capital level, growth and population dynamics, introducing fertility choice in macro-dynamic models. This study goes one step further by also highlighting the link with pollution. The authors developed a simple overlapping generations model with paternalistic altruism according to wealth and environmental concerns. This, then, can explain a simultaneous increase in capital intensity, population growth and pollution, namely a polluting industrialization. The authors show in addition that a permanent productivity shock, possibly associated to technological innovations, promotes such a polluting development process, escaping a trap where the economy is relegated to low levels of capital intensity, population growth and pollution.

14/03600 Review on clean development mechanism (CDM) implementation in Malaysia

Lim, X.-L. and Lam, W.-H. *Renewable and Sustainable Energy Reviews*, 2014, 29, 276–285.

The Clean Development Mechanism (CDM) appears to be a catalyst to reduce the cost of renewable energy projects in Malaysia. Carbon credits gained from developed countries enhance the financial state of the nation and potentially push forward renewable energy industries. Most of the registered CDM projects are related to renewable energy, which recorded 69% out of total projects. This paper used data from GreenTech Malaysia in order to present the CDM projects in the energy sector. The institutional framework has been discussed to demonstrate the registration in the CDM cycle. Although the extent of CDM's success is controversial, the number of registered CDM projects in the energy sector is rising and helps in a large amount of emission reductions in Malaysia, particularly through biomass and biogas projects. CDM should encourage more new renewable technology including wind energy and tidal energy in Malaysia.

14/03601 Role of technologies in energy-related CO_2 mitigation in China within a climate-protection world: a scenarios analysis using REMIND

Zhang, S. *et al. Applied Energy*, 2014, 115, 445–455.

In a world that needs climate protection through emissions reduction, China's domestic mitigation will be put on the national agenda. The large-scale deployment of innovative technologies induced by climate policies is a key determinant for reducing emissions in an effective and efficient manner. A distinguishing feature of the Chinese energy sector (especially electricity generation), is that investment costs are significantly lower than in other world regions. Represented in the methodological framework of the augmented REMIND model, three promising mitigation technologies (also known as technology clusters) in the electricity sector: carbon dioxide capture and storage (CCS) with advanced coal-generation technologies, nuclear, and renewables are the focus of this study. The scenarios are designed to analyse the roles of these technologies and their associated economic impacts under a

climate policy (i.e. a carbon tax). The results indicate the following. (1) Technology policies improving the techno-economic features of low-carbon technologies are insufficient to restrain China's increasing emissions. (2) Carbon-pricing policies can effectively reduce emissions by making low-carbon options more competitive than conventional fossil fuel alternatives. In the global carbon tax regime framed in this paper, China's mitigation potential is larger than that of any of other region and the peak of emissions occurs earlier (by 2020) and is 50% lower than in the BASE scenario. (3) CCS is important, but the window of opportunity for its deployment is limited to the near- to mid-term future. It is important to lower the cost of the carbon tax by supplying CCS technology; however, the gains from CCS for the 'myopic' fossil fuel sectors are limited, compared to the case without CCS. Therefore, strong social support for CCS development should be implemented, if it is to be an effective mitigation option. (4) The cost of nuclear is a major determinant of the future development pattern in China's power sector. Renewables are the long-term solution (with large-scale deployment only after 2030, solar PV in particular) for deep emissions mitigation. The creative policies reflected by alternative investment, technology innovation, and climate protection strategies should be explored and implemented to make use of their long-term potential.

14/03602 Satisfaction of occupants toward indoor environment quality of certified green office buildings in Taiwan

Liang, H.-H. *et al. Building and Environment*, 2014, 72, 232–242.

The preservation of indoor environmental quality (IEQ) is key to the well-being and productivity of office occupants. In Taiwan, the green building certification system established IEQ criteria to evaluate the performance of buildings in acoustics, lighting, ventilation and decoration but not the performance in delivering thermal comfort. This study investigated and compared the green and conventional office buildings in middle Taiwan on various aspects of IEQ during a period of active air-conditioning use. Among the monitored environmental variables, the levels of noise, illumination, and carbon dioxide in both types of buildings were in compliance with international or Taiwan's regulatory standards, but not that of volatile organic compounds. The degrees of overall IEQ satisfaction as well as the proportion of occupants voting for satisfaction in the green buildings were both greater than their counterparts in the conventional buildings. Of the specific areas of IEQ evaluated, including the acoustics, lighting, perception of thermal comfort of the occupants toward the thermal environment, and indoor air quality, a statistically significant difference was found between the mean score of satisfaction in the green buildings and that in the conventional buildings. The occupants sharing a concern on energy conservation were more amenable to slightly deficient IEQ. The system of green building certification in Taiwan was able to facilitate proper IEQ performance of the buildings, although a re-visit of the current criteria to incorporate thermal comfort-related criteria may be adequate.

14/03603 Stakeholder-associated risks and their interactions in complex green building projects: a social network model

Yang, R. J. and Zou, P. X. W. *Building and Environment*, 2014, 73, 208–222.

Previous research on risks in complex green building projects has mainly focused on what the risks are and how they may impact on project objectives. Such studies have tended toward an inward-looking perspective that treats risks in isolation from one another. In reality, most risks are interrelated and associated with internal or external project stakeholders. To address this research gap, this current research developed a social network analysis-based stakeholder-associated risk analysis method to assess and analyse the risks and their interactions in complex green building projects. A case study was conducted to highlight the green-specific risks and their profiles, together with the proposed mitigation actions. The research results presented in this paper may broaden researchers and construction professionals' awareness of influential risks in green building projects and enhance their ability to perceive, understand, assess, and mitigate the risks in an effective and efficient way; thereby achieving higher performance in strategic risk management and stakeholder communication in green building project management.

14/03604 State-of-the-art analysis of the environmental benefits of green roofs

Berardi, U. *et al. Applied Energy*, 2014, 115, 411–428.

Green roofs have been proposed for sustainable buildings in many countries with different climatic conditions. A state-of-the-art review of green roofs emphasizing current implementations, technologies, and benefits is presented in this paper. Technical and construction aspects of green roofs are used to classify different systems. Environmental benefits are then discussed mainly by examining measured performances. By reviewing the benefits related to the reduction of building energy consumption, mitigation of urban heat island effect, improvement of air pollution, water management, increase of sound insulation, and ecological preservation, this paper shows how green roofs may contribute to more sustainable buildings and cities. However, an efficient integration of green roofs needs to take into account both the specific climatic conditions and the characteristics of the buildings. Economic considerations related to the life-cycle cost of green roofs are presented together with policies promoting green roofs worldwide. Findings indicate the undeniable environmental benefits of green roofs and their economic feasibility. Likewise, new policies for promoting green roofs show the necessity for incentivizing programmes. Future research lines are recommended and the necessity of cross-disciplinary studies is stressed.

14/03605 The use of zero-valent iron for groundwater remediation and wastewater treatment: a review

Fu, F. *et al. Journal of Hazardous Materials*, 2014, 267, 194–205.

Recent industrial and urban activities have led to elevated concentrations of a wide range of contaminants in groundwater and wastewater, which affect the health of millions of people worldwide. In recent years, the use of zero-valent iron (ZVI) for the treatment of toxic contaminants in groundwater and wastewater has received wide attention and encouraging treatment efficiencies have been documented. This paper gives an overview of the recent advances of ZVI and progress obtained during the groundwater remediation and wastewater treatment utilizing ZVI (including nanoscale ZVI) for the removal of: (a) chlorinated organic compounds, (b) nitroaromatic compounds, (c) arsenic, (d) heavy metals, (e) nitrate, (f) dyes and (g) phenol. Reaction mechanisms and removal efficiencies were studied and evaluated. It was found that ZVI materials with wide availability have appreciable removal efficiency for several types of contaminants. Concerning ZVI for future research, some suggestions are proposed and conclusions have been drawn.

14/03606 We want to sort! Assessing households' preferences for sorting waste

Czajkowski, M. *et al. Resource and Energy Economics*, 2014, 36, (1), 290–306.

There are two major ways in which solid waste can be sorted and recycled: at the household level, when households are required to sort waste into a given number of categories, or in specialized sorting facilities. Traditionally, it has been thought that sorting at the household level is an inconvenience, as it uses space and requires time and effort. This study provides empirical evidence to the contrary, indicating that home sorting is a net source of utility for some people. Through a carefully designed choice experiment, the authors collected stated choices from members of a Polish municipality with respect to the way their waste is sorted and how often it is collected. In the hypothetical scenario employed, respondents were informed that waste will be sorted anyway – if not at the household level then at a specialized sorting facility. Interestingly, analysis shows that a large group of people are willing to sort waste at the household level even if unsorted waste would be collected at no extra cost. For a minority, increased home sorting of waste would, however, impose a loss of utility. Overall, the results indicate that most respondents preferred to sort waste themselves if given the choice. The authors provide a few possible explanations of this perhaps surprising result, including the desire to promote a green external image, and a concern about the effectiveness of separation activities performed by others.

CO_2, NO_x, SO_2 and particulate emissions

14/03607 Analysis of uncertainties in the estimates of nitrous oxide and methane emissions in the UK's greenhouse gas inventory for agriculture

Milne, A. E. *et al. Atmospheric Environment*, 2014, 82, 94–105.

The UK's greenhouse gas inventory for agriculture uses a model based on the IPCC Tier 1 and Tier 2 methods to estimate the emissions of methane and nitrous oxide from agriculture. The inventory calculations are disaggregated at country level (England, Wales, Scotland and Northern Ireland). Before now, no detailed assessment of the uncertainties in the estimates of emissions had been done, Monte Carlo simulation was used to do such an analysis. Information on the uncertainties of each of the model inputs was collated. The uncertainties propagate through the model and result in uncertainties in the estimated emissions. Using a sensitivity analysis, it was found that in England and Scotland the uncertainty in the emission factor for emissions from N inputs (EF_1) affected uncertainty the most, but that in Wales and Northern Ireland, the emission factor for N leaching and runoff (EF_5) had greater influence. The study showed that if the uncertainty in any one of these emission factors is reduced by 50%, the

uncertainty in emissions of nitrous oxide reduces by 10%. The uncertainty in the estimate for the emissions of methane emission factors for enteric fermentation in cows and sheep most affected the uncertainty in methane emissions. When inventories are disaggregated (as that for the UK is) correlation between separate instances of each emission factor will affect the uncertainty in emissions. As more countries move towards inventory models with disaggregation, it is important that the IPCC give firm guidance on this topic.

14/03608 Can the long-term potential for carbonatization and safe long-term CO_2 storage in sedimentary formations be predicted?

Hellevang, H. and Aagaard, P. *Applied Geochemistry*, 2013, 39, 108–118.

A sedimentary formation perturbated by supercritical CO_2 reacts by dissolving primary minerals and forming new secondary phases. In this process CO_2 may be trapped in stable carbonate minerals and may thereby be immobilized for long time spans. The potential for mineral trapping can be estimated by solving kinetic expressions for the reservoir minerals and possible secondary phases. This is, however, not trivial as kinetic data are uncertain or even lacking for the minerals of interest. Here, the rate equations most commonly used for CO_2 storage simulations have been solved, and the rate parameters varied, to obtain sensitivity on the total amount of CO_2 stored as mineral carbonate. As various expressions are in use to estimate growth rates of secondary carbonates, three formulations were compared, including one taking into account mineral nucleation preceding growth. The sensitivity studies were done on two systems, the Utsira sand being representative for a cold quartz-rich sand (37 °C, 100 bar CO_2), and the Gulf Coast sediment, being representative for a medium temperature quartz–plagioclase-rich system (75 °C, 300 bar CO_2). The simulations showed that the total predicted CO_2 mineral storage is especially sensitive to the choice of growth rate model and the reactive surface area. The largest sensitivity was found on α, fraction of total surface area available for reactions, with a reduction of one order of magnitude for all reacting phases leading to three to four times lower predicted CO_2 mineral storage. Because the reactive surface area is highly uncertain for natural systems, the range in predicted results may be even larger. The short-term predictions (<100–1000 a), such as the onset of carbonate growth, were highly sensitive to nucleation and growth rates. Moreover, the type of carbonate minerals formed was shown to be model dependent, with the simplest model predicting an unlikely carbonate assemblage at low temperature (i.e. formation of dolomite at 37 °C). Therefore, to use kinetic models to upscale short-term (< months) laboratory experiments in time, to identify the past reactions and physical conditions of natural CO_2 storage analogues, and finally to predict the potential for CO_2 trapping in existing and future storage projects, more knowledge has to be collected, especially on the reactive surface area of CO_2 storage reservoirs, and on the rate of secondary carbonate nucleation and growth.

14/03609 Carbon dioxide emission and heat release estimation for Pantelleria Island (Sicily, Italy)

Granieri, D. *et al. Journal of Volcanology and Geothermal Research*, 2014, 275, 22–33.

Detailed surveys of diffuse CO_2 flux, soil temperature, thermal gradients, and sampling of high-T fumaroles were carried out in the Favare area and Lake Specchio di Venere on Pantelleria Island. Spatial patterns of diffuse CO_2 emissions in the Favare area reflect structural discontinuities (faults, fractures or cracks in the soil) associated with the volcano-tectonic structures of the young Monastero Caldera (NNE–SSW to NE–SW trending). The estimated diffuse CO_2 output from two adjacent sites in the Favare area ($\sim$93,000 m^2) is 7.8 t d^{-1} (equivalent to 2.62 kt a^{-1}), whereas that from the west shore of the lake (450 m^2) is 0.041 t d^{-1} (or 0.015 kt a^{-1}). The extrapolation of diffuse CO_2 fluxes across the entire altered area of Favare suggests that CO_2 emissions are $\sim$19.3 t d^{-1}. The diffuse CO_2 flux correlates with shallow soil temperatures, indicating a similar source for both the heat and volatiles from the underlying geothermal reservoir. Gas equilibria applied to fumarolic effluents define P–T conditions for this reservoir at 2–6 bar and 120–160 °C, in good agreement with measurements from exploratory wells in these areas (e.g. 135 °C at a depth of 290 m). Using the CO_2 flux as a tracer for steam output, and consequently for heat flow, the calculated thermal energy for the shallow reservoir is 10–12 MW; this represents the minimum geothermal potential of the reservoir on Pantelleria island.

14/03610 Carbonate dissolution in Mesozoic sand- and claystones as a response to CO_2 exposure at 70 °C and 20 MPa

Weibel, R. *et al. Applied Geochemistry*, 2014, 42, 1–15.

The response to CO_2 exposure of a variety of carbonate cemented rocks has been investigated using pressurized batch experiments conducted under simulated reservoir conditions, 70 °C and 20 MPa, and with a durations of up to 14 months. Calcite, dolomite, ankerite and siderite cement were present in the unreacted reservoir rocks and caprocks. Core plugs of the reservoir rocks were used in order to investigate the alterations *in situ*. Crushing of the caprock samples was necessary to maximize reactions within the relatively short duration of the laboratory experiments. Synthetic brines were constructed for each batch experiment to match the specific formation water composition known from the reservoir and caprock formations in each well. Chemical matched synthetic brines proved crucial in order to avoid reactions due to non-equilibra of the fluids with the rock samples, for example observations of the dissolution of anhydrite, which were not associated with the CO_2 injection, but rather caused by mismatched brines. Carbonate dissolution as a response to CO_2 injection was confirmed in all batch experiments by both petrographical observations and geochemical changes in the brines. Increased Ca and Mg concentrations after a 1-month reaction with CO_2 and crushed caprocks are ascribed to calcite and dolomite dissolution, respectively, though not verified petrographically. Ankerite and possible siderite dissolution in the sandstone plugs are observed petrographically after a 7-month reaction with CO_2; and are accompanied by increased Fe and Mn contents in the reacted fluids. Clear evidence for calcite dissolution in sandstone plugs is observed petrographically after 14 months of reaction with CO_2, and is associated with increased amounts of Ca (and Mg) in the reacted fluid. Dolomite in sandstones shows only minor dissolution features, which are not clearly supported by increased Mg content in the reacted fluid. Silicate dissolution cannot be demonstrated, either by chemical changes in the fluids, as Si and Al concentrations remain below the analytical detection limits, nor by petrographical changes, as partly dissolved feldspar grains and authigenic analcime are present in the sediments prior to the experiments. It is noteworthy, that authigenic K-feldspar and authigenic albite in sandstones show no signs of dissolution and consequently seem to be stable under the experimental conditions.

14/03611 Combination of CO_2 geological storage with deep saline water recovery in western China: insights from numerical analyses

Li, Q. *et al. Applied Energy*, 2014, 116, 101–110.

CO_2 geological storage, when combined with deep saline water recovery (CO_2-EWR), not only achieves the relatively secure storage of CO_2 that was captured from the coal chemical industry, due to lower pressure, but also enhances saline water for drinking and industrial or agricultural utilization. This storage will undoubtedly become a win–win choice for the enhancement of energy security and for the promotion of regional development in China, particularly for western regions with a relative shortage of water resources and a more fragile ecological environment. In this paper, a three-dimensional injection–extraction model is established that uses the TOUGH2/ECO2N program according to typical formation parameters of a coal chemical industry in the Xinjiang Uyghur Autonomous Region. Numerical results showed that under the guarantee of sufficient water conditions, 1.73×10^8 tons of saline water could be produced when the CO_2-EWR is adopted. Well arrangements and formation parameters are also analysed, and the following conclusions can be drawn: arrangements of pumping wells, such as pumping well number, pumping rate and distance, have considerable influences on the reservoir pressure, and in addition, the sensitivity of pressure on the distance and pumping rate decreases as their values increase. In view of these features, it is necessary to find an optimal point to achieve the best combination of pressure, the leakage time and the amount of dissolution. Formation parameters primarily control the mechanism of CO_2 migration and dissolution. Salinity in the salt water has the greatest impact on CO_2 dissolution trapping followed by permeability and porosity. The arrival time that is allowable for saline water production primarily depends on porosity followed by the permeability ratio and the arrangements of pumping wells. The reservoir pressure change that is caused by parameters is not obvious compared with setting pumping wells. Overall, CO_2-EWR technology is a potential strategic choice for China, particularly in western regions. Additionally, the analysis results provide a reliable guide and reference for CO_2 storage site selection, as well as the practical arrangements of wells.recovery

14/03612 Comparison of the gaseous and particulate matter emissions from the combustion of agricultural and forest biomasses

Brassard, P. *et al. Bioresource Technology*, 2014, 155, 300–306.

The aim of this study was to compare gaseous and particulate matter (PM) emissions from the combustion of agricultural (switchgrass, fast-growing willow and the dried solid fraction of pig manure) and forest (wood mixture of Black Spruce and Jack Pine) biomasses in a small-scale unit (17.58 kW). Concentrations of CO_2, CO, CH_4, NO_2, NH_3, N_2O, SO_2, HCl and H_2O were measured by Fourier transform infrared spectroscopy and converted into emission rates. Opacity was also evaluated and particulates were sampled. Results showed significantly higher emissions of SO_2, NO_2 and PM with the combustion of agricultural biomass compared to the forest biomass. However, further

studies should be carried out so regulations can be adapted in order to permit the combustion of agricultural biomass in small-scale combustion units.

14/03613 CO_2 capture by membrane absorption coupling process: application of ionic liquids

Lu, J.-G. *et al. Applied Energy*, 2014, 115, 573–581.

An experiment system made up of a membrane absorption unit and a membrane vacuum regeneration unit was set up. Ionic liquids (ILs), 1-butyl-3-methyl-imidazolium tetrafluoroborate ([bmim][BF_4]) and 1-(3-aminopropyl)-3-methyl-imidazolium tetrafluoroborate ([apmim][BF_4]) as two absorbents for CO_2 capture, were applied to the experiment system. Coupling processes of membrane contactor-IL absorbents and membrane vacuum-IL regenerations were evaluated by both the membrane absorption unit and the membrane vacuum regeneration unit. Water content in the ILs, CO_2 loading capacity, operation conditions and modes, and regeneration factors were investigated. Results show that lower water content in [apmim][BF_4] and higher water content in [bmim][BF_4] were favourable for the coupling process. The aqueous [apmim][BF_4] could give a high CO_2 loading capacity at almost atmospheric pressure and its absorption capability was much larger than that of [bmim][BF_4] in the coupling process. CO_2 partial pressure had a certain influence on the membrane fluxes of both the ILs. The liquid flowrate evidently affected the membrane flux of the coupling process with aqueous [apmim][BF_4]. The aqueous [apmim][BF_4] could maintain a higher initial membrane flux and give a much larger instantaneous membrane flux compared with the aqueous [bmim][BF_4]. The aqueous [bmim][BF_4] could be completely regenerated even at low vacuum degree, while the aqueous [apmim][BF_4] was difficult to be regenerated comparatively even at high vacuum degree.

14/03614 CO_2 capture from PCC power plants using solid sorbents: bench scale study on synthetic gas

Ruiz, E. *et al. Fuel*, 2013, 114, 143–152.

Much attention is paid currently to global warming effect thought to be due to CO_2 emissions. Physical adsorption of CO_2 using regenerable sorbents is a promising approach for CO_2 capture from flue gases. The objective of this work was to study the potential for CO_2 capture of different sorbents at a representative scale and under realistic conditions resembling those of flue gases after the desulfurization tower of conventional pulverized coal combustion (PCC) plants. First, comparative adsorption–desorption studies for CO_2/N_2 mixtures were performed for different sorbents: one alumina-based, one zeolitic-type and one activated carbon. The zeolitic type sorbent was identified as most promising and was subjected to a subsequent in-depth study of its stability, tolerance to poisoning and durability over cycles. Short-term tests were performed to assess the effect of competitive adsorption, e.g. H_2O, and deactivation due to SO_2 and NO_x. Long-term tests were conducted to study the effect of the number of adsorption–desorption cycles. CO_2 adsorption breakthrough curves (exit CO_2 concentration about 1%) of the fresh zeolitic material under different gas compositions were obtained. The addition of water had a detrimental effect on CO_2 adsorption, shifting CO_2 breakthrough curve to shorter times, probably due to competitive adsorption of H_2O. The simultaneous presence of H_2O and SO_2 has a synergistic negative effect on CO_2 adsorption. However, when H_2O, SO_2 and NO coexist in the testing gas, the synergistic negative effect on CO_2 adsorption is slightly attenuated. The adsorbent was also studied on consecutive adsorption–desorption cycles under the different gas compositions. In all cases, there was a certain loss in CO_2 adsorption capacity on passing from the first to the second cycle, being almost constant in successive cycles.

14/03615 Detection of greenhouse gas precursors from ethanol powered vehicles in Brazil

Tavares, J. R. *et al. Biomass and Bioenergy*, 2014, 61, 46–52.

The use of fossil fuels in the transportation sector has caused the emissions of various air pollutants that can cause damage to the atmosphere and to human health. In order to minimize pollutant emissions, the Brazilian government has encouraged the use of alternatives fuels such as ethanol. Ethanol can be a great ally in global warming mitigation due to its potential to reduce carbon dioxide emissions in its renewable cycle. Other pollutant gases emitted during ethanol combustion can contribute directly or indirectly to intensify global warming. In this study, photoacoustic and electrochemical sensors were used to detect greenhouse precursor gases, such as carbon monoxide, nitrogen oxides and especially ethylene, a primary pollutant in the generation of tropospheric ozone, in the exhaust of ethanol powered vehicles, in the range of parts per million by volume.

14/03616 Effects of small-scale turbulence on NO_x formation in premixed flame fronts

Ren, Z. *et al. Fuel*, 2014, 115, 241–247.

Turbulent lean premixed combustion plays a predominant role in reducing NO_x emissions due to the low flame temperatures. For turbulent premixed flames located in the thin-reaction-zones regime, small-scale eddies could penetrate into the preheat zone of the flames and enhance the mixing process. In this study, the effects of small-scale turbulence on NO_x formation in premixed flame fronts are investigated through the incorporation of turbulence induced diffusion in the preheat zone of one-dimensional premixed flames for methane/air, simulated with the 53-species GRI-Mech 3.0 mechanism at both atmospheric pressure and engine conditions with different turbulence intensities. It is found that the NO generated in flame fronts decreases with increased intensity of small-scale turbulence and the effect is more pronounced at high pressures, where the turbulence-induced diffusion in the preheat zone can reduce the NO_x formation in flame fronts by more than 40%. In addition, a flamelet-based approach that accounts for the flame thickening effects has been formulated to simulate NO_x formation in turbulent lean premixed combustion. In this approach, the species NO is transported and solved in a simulation with its chemical source term modelled by combining its formation in flame fronts and its integrated formation rate in the post-flame zone from one-dimensional premixed flames with detailed chemical kinetics and turbulence induced diffusion.

14/03617 Evaluation of building characteristics in 27 dwellings in Denmark and the effect of using particle filtration units on $PM_{2.5}$ concentrations

Spilak, M. P. *et al. Building and Environment*, 2014, 73, 55–63.

Exposure to airborne particulate matter (PM) in homes is associated with the risk of cardiovascular diseases and respiratory problems. Due to the extended time people spend at home, reducing the particle concentration in homes may be a means to reduce the risk of cardiovascular diseases and respiratory problems. Use of particle filtration units (PFUs) might be an effective way for rapid removal of indoor PM. In a randomized cross-over design, the custom built PFUs ran for 2 weeks in each of two modes: with or without the inclusion of a HEPA filter. The authors assessed the association between the concentration levels of particulate matter and building characteristics; and the use of PFU as a way to effectively reduce the levels of $PM_{2.5}$ indoors. The results obtained from the study have shown that a small room area, wooden floor material, or the use of gas for cooking is strongly associated with high $PM_{2.5}$ mass concentrations. Furthermore, the winter period and a location farther from a trafficked street were associated with increased $PM_{2.5}$ mass. Overall, the use of PFU led to a decrease in the concentrations of $PM_{2.5}$ of 54.5% (median value). The PFU particle-removal efficiency was assessed by using the amount of infiltrated air, size of the controlled room and filtration effectiveness.

14/03618 Flow dependent water quality impacts of historic coal and oil shale mining in the Almond River catchment, Scotland

Haunch, S. *et al. Applied Geochemistry*, 2013, 39, 156–168.

The Almond River catchment in central Scotland has experienced extensive coal mining during the past 300 years and also provides an example of enduring pollution associated with historic unconventional hydrocarbon exploitation from oil shale. Detailed spatial analysis of the catchment has identified over 300 abandoned mine and mine waste sites, comprising a significant potential source of mine-related contamination. River water quality data, collected over a 15-year period from 1994 to 2008, indicates that both the coal and oil shale mining areas detrimentally impact surface water quality long after mine abandonment due to the continued release of Fe and SO_4^{2-} associated with pyrite oxidation at abandoned mine sites. Once in the surface water environment Fe and SO_4^{2-} display significant concentration-flow dependence: Fe increases at high flows due to the re-suspension of river bed Fe precipitates ($Fe(OH)_3$); SO_4^{2-} concentrations decrease with higher flow as a result of dilution. Further examination of Fe and SO_4 loading at low flows indicates a close correlation of Fe and SO_4^{2-} with mined areas; cumulative low flow load calculations indicate that coal and oil shale mining regions contribute 0.21 and 0.31 g/s of Fe, respectively, to the main Almond tributary. Decreases in Fe loading along some river sections demonstrate the deposition and storage of Fe within the river channel. This river bed Fe is re-suspended with increased flow resulting in significant transport of Fe downstream with load values of up to 50 g/s Fe. Interpretation of major ion chemistry data for 2005–2006 indicates significant increases in Ca^{2+}, Mg^{2+} and HCO_3^- in coal mined areas probably as a result of the buffering of proton acidity in mine waters; in the oil shale areas Na^- and Cl^- become increasing dominant possibly associated with increased urbanization and saline pore water discharge from unprocessed oil shale waste. The study demonstrates the importance of considering the cumulative impact of point and diffuse contamination sourced from numerous small coal and oil shale mine sites on surface water quality.

14/03619 Hydrate-based technology for CO_2 capture from fossil fuel power plants

Yang, M. *et al. Applied Energy*, 2014, 116, 26–40.

Hydrate-based CO_2 capture is a promising technology. To obtain fundamental data for a flowing system, the authors measured the distribution of pore solution to analyse hydrate formation/dissociation and gas separation properties. An orthogonal experiment was carried out to investigate the effects of glass beads, flow rates, pressures and temperatures on it. Magnetic resonance imaging (MRI) images were obtained using a spin echo multi-slice pulse sequence. Hydrate saturations were calculated quantitatively using an MRI mean intensity. The results show that hydrate blockages were frequently present. During the hydrate formation and dissociation process, the movement of the solution occurred in cycles. However, the solution movement rarely occurred for residual solution saturations obtained with a high backpressure. The solution concentrate phenomenon occurred mostly in BZ-04. The highest hydrate saturation was 30.2%, and the lowest was 0.70%. Unlike that in BZ-01, there was no stability present in BZ-02 and BZ-04. The different CO_2 concentrations for the three processes of each cycle verified hydrate formation during the gas flow process. The highest CO_2 concentration was 38.8%, and the lowest one was 11.4%. To obtain high hydrate saturation and good separation effects, the values of 5.00 MPa, 1.0 ml min^{-1} and 280.00 K were chosen. For the gas flow process, only the pressure had a significant impact on gas composition, and all the factors had a significant impact on the gas composition of the depressurization process. The temperature had a significant impact on the gas composition of the hydrate dissociation process. The flow rate did not have a significant impact on the composition of the depressurization process.

14/03620 Impact of nitrogen oxides (NO, NO_2, N_2O) on the formation of soot

Abián, M. *et al. Combustion and Flame*, 2014, 161, (1), 280–287.

The emission of both nitrogen oxides and soot from combustion processes is still a matter of concern. When a flue gas recirculation (FGR) technique is applied, the presence of a given nitrogen oxide in the recirculated mixture can affect the emissions of other pollutants, such as soot, and be used for its control in a combustion process. In this context, the present work is focused on the identification of the effect of the main nitrogen oxides (NO, NO_2 and N_2O) present in combustion systems on soot and main product gases formation from the pyrolysis of ethylene, at atmospheric pressure and in the 975–1475 K temperature range. The experimental results are examined to assess the effectiveness of each nitrogen oxide in suppressing or boosting soot formation, to achieve the possible nitrogen oxides reduction, and to identify the elementary steps involved in the nitrogen oxides and ethylene conversion as function of the different nitrogen oxides. This analysis is supported on model calculations. The main results indicate that the presence of nitrogen oxides influences the formation of soot, yielding different results depending on the nitrogen oxide added, its initial concentration and the reaction temperature. Among the different nitrogen oxides studied (NO, NO_2 and N_2O), the lowest sooting tendency has been achieved in the presence of NO_2, followed by NO and finally N_2O. Different mechanisms appear to be responsible for soot and nitrogen oxides reduction, including both oxidation and reburn type reactions. Furthermore, representative soot samples formed from the different C_2H_4–nitrogen oxide mixtures have been characterized through elemental analysis, Brunauer–Emmett–Teller surface area analysis and transmission electron microscopy in order to explore the influence, if any, of the nitrogen oxide present.

14/03621 Improving air quality in high-density cities by understanding the relationship between air pollutant dispersion and urban morphologies

Yuan, C. *et al. Building and Environment*, 2014, 71, 245–258.

In high-density megacities, air pollution has a higher impact on public health than cities of lower population density. Apart from higher pollution emissions due to human activities in densely populated street canyons, stagnated air flow due to closely packed tall buildings means lower dispersion potential. The coupled result leads to frequent reports of high air pollution indexes at street-side stations in Hong Kong. High-density urban morphologies need to be carefully designed to lessen the ill effects of high density urban living. This study addresses the knowledge-gap between planning and design principles and air pollution dispersion potentials in high density cities. The air ventilation assessment for projects in high-density Hong Kong is advanced to include air pollutant dispersion issues. The methods in this study are computational fluid dynamics simulation and parametric study. The SST κ–ω model is adopted after balancing the accuracy and computational cost in the comparative study. Urban-scale parametric studies are conducted to clarify the effects of urban permeability and building geometries on air pollution dispersion, for both the outdoor pedestrian environment and the indoor environment in the roadside buildings. Given the finite land resources in high-density cities and the numerous planning and design restrictions for development projects, the effectiveness of mitigation strategies is evaluated to optimize the benefits. A real urban case study is finally conducted to demonstrate that the suggested design principles from the parametric study are feasible in the practical high density urban design.

14/03622 Influencing factors on NO_x emission level during grate conversion of three pelletized energy crops

Díaz-Ramírez, M. *et al. Applied Energy*, 2014, 115, 360–373.

NO_x emission behaviour of three different pelletized energy crops, a herbaceous one, *Brassica carinata*, a short rotation coppice, *Populus* sp., and a blend of them, was assessed during fixed grate conversion. Measurements of NO_x emissions were done at combustion conditions that yielded both thermal efficiency and CO emissions according to the European norm (EN 303–5:2012), and results compared to limits established by the Austrian deviations. Based on the experimental data, NO_x results fulfilled the Austrian restrictions except during combustion of brassica, which exhibited the highest fuel-N content. The fuel-NO_x was identified as the main formation mechanism. An opposite relation was determined between the specific NO_x emissions and the fuel-N conversion ratio obtained between the N-rich and the N-lean fuels tested here. The influence of the air supply (amount and distribution) on the NO_x formation was also noticeable. In general, a higher proportion of air increased the specific NO_x emissions and the fuel-N conversion ratio. Possibilities to control the NO_x emissions level by air staging were rather limited, particularly, during combustion of brassica and the blend because of their peculiarities as ash-rich fuels with high slag formation risk. For attaining an appropriate conversion of these fuels, primary air requirements substantially increased. Due to limitations found during the energy crops conversion, efforts to minimize the level of NO_x emissions identified here for the troublesome fuels tested should be mainly focused on attaining both a properly designed air supply system and the grate temperature control as well as on conditioning the fuel-N content, for instance, by blending.

14/03623 Multivariate monitoring of a carbon dioxide removal process

Dunia, R. *et al. Computers & Chemical Engineering*, 2014, 60, 381–395.

Process hardware improvements have significantly increased the amount of information collected in industrial facilities, which allows the use of tools such as multivariable statistical analysis for process monitoring. Nevertheless, such statistical models tend to be static and extremely general when implemented in process facilities with several modes of operation, as is the case of carbon dioxide removal processes. This work demonstrates the use of multivariable statistical analysis for process transitions between different modes of operation. Continuous process analytics are used to define key variables, named 'state variables', to determine the current mode of operation. This work also makes use of parallel coordinates to illustrate the simultaneous visualization of several transition paths and statistical tests. Such tests apply confidence limits that are appropriate to the current mode of operation. This methodology is successfully tested in the CO_2 capture plant at the University of Texas in Austin, USA. The results show the effectiveness of using this type of application to detect abnormal operating conditions at different levels of operations.

14/03624 Potential CO_2 savings through biomethane generation from municipal waste biogas

Starr, K. *et al. Biomass and Bioenergy*, 2014, 62, 8–16.

An alternative source of methane that can also reduce the greenhouse gas effect is one that comes from the upgrading of biogas. This paper studies eight technologies through life cycle assessment (LCA). Six of the technologies are ones that are already on the market and the two others are novel technologies that use carbon mineralization to store CO_2 on their removal. The two novel technologies include alkaline with regeneration (AwR) and bottom ash upgrading (BABIU). These technologies use waste rich in calcium, from municipal solid waste incinerators (MSWI), to store the CO_2 from biogas. Among all conventional technologies, high pressure water scrubbing and chemical scrubbing with amine had the lowest CO_2 impacts. Of the novel technologies BABIU saves 10% more CO_2 than AwR. An uncertainty analysis and a material flow analysis demonstrated that proximity to a MSWI is an important factor to consider. As well, it was seen that while the technology is promising it cannot be applied to an entire country if the proper infrastructure is not in place.

14/03625 Sources of the potential CO_2 emission reduction in China: a nonparametric metafrontier approach

Du, K. *et al. Applied Energy*, 2014, 115, 491–501.

Taking the underlying technology heterogeneity into account, this paper uses a non-parametric metafrontier approach to estimate the CO_2 emission efficiency and the potential emission reduction of China's 30 provinces for the period 2006–2010. The sources of the potential emission reduction are identified as managerial failure and technology gap. The proposed models are estimated using linear programming method. The main findings are as follows. First, the

potential CO_2 emission reduction is on average 56.2 million tons for each province, and 1687 million tons for the whole country. Second, over half of the potential emission reduction is caused by technology gap. Third, the major contributor to the potential emission reduction varies across different regions, as management inefficiency for the east area and technology gap for the central and west areas.

Hydrocarbon emissions

14/03626 Exhaust emissions of polycyclic aromatic hydrocarbons, *n*-alkanes and phenols from vehicles coming within different European classes

Perrone, M. G. *et al. Atmospheric Environment*, 2014, 82, 391–400.

European Union emission standards for vehicles do not include many particulate (PM) and gaseous species, despite their considerable impact on air pollution and health. Emission factors (EFs) were measured for unregulated species, i.e. polycyclic aromatic hydrocarbons (PAHs) and *n*-alkanes (ALKs) in the particle phase, and, for the first time, EFs for phenols in both particle and gas phases. Exhaust samples were collected under controlled operating conditions (chassis dynamometer tests) for in-service vehicles (private cars, PCs and light duty vehicles, LDVs) from different EURO classes. EFs of trace organics were highest for the old EURO 1 vehicles (the tested EURO 1 vehicles were without emission-control devices), and lowest for the more recent EURO 3 and 4 vehicles. ALKs (C20–C32) were the most abundant trace organic compounds found in PM vehicle exhaust, and their EF ranged between 2034 and 101 $\mu g\,km^{-1}$(EURO 1–4 LDVs). PM-phased phenols EFs were in the range 0.42–2.50 $\mu g\,km^{-1}$, and 4-nitrophenol was the most abundant one. The highest EFs were measured for phenols in the gas phase (dominated by the presence of phenol) for gasoline EURO 1 ($43.16 \pm 9.99\,\mu g\,km^{-1}$). Emissions of PAHs changed depending on the fuel used. The PAH EFs of diesel-driven PCs were four to five times higher than those of gasoline vehicles, with PAHs diesel exhaust being mainly enriched in low four-ring PAHs (85%), while five- to six-ring PAHs were prevalent (55%) in gasoline vehicles. Results of source profiles from chassis dynamometer tests were compared with ambient data, and the traffic PAH source profile derived from a tunnel study (Milan) agreed with the estimated emissions from a mix of diesel and gasoline vehicles circulating in the same area. Moreover, the impact of EURO regulatory changes on exhaust emissions was calculated, and this made it possible to estimate the downward trend of PAH emissions in the Province of Milan in the period 2005–2020.

14/03627 Experimental design approach to the optimisation of hydrocarbons extraction from the sediment: method development and application

Net, S. *et al. Applied Geochemistry*, 2014, 40, 126–134.

Extraction and analysis of organic pollutants from matrices such as sediment constitute an essential step in environmental research. However, the extraction for quantitative analysis can turn out to be difficult because these compounds are present in trace levels and can be strongly bound to the sorbent matrix. Consequently, accuracy of environmental analyses mainly depends on the efficiency and the robustness of the extraction step. In this work, a sequential accelerated solvent extraction procedure was applied to the extraction of polycyclic aromatic and aliphatic hydrocarbons (PAHs, Me-PAHs and *n*-alkanes) in sediment samples. The extraction protocol was developed for 26 PAHs, including the 16 PAHs of the US Environmental Protection Agency priority list, for 17 alkylated PAHs homologues and for 29 *n*-alkanes (from *n*-C_{12} to *n*-C_{40}). A set of 30 experiments was carried out for the determination of the optimal extraction conditions. The four parameters studied were pressure, temperature, extraction time and nature of the solvent. Extracts were analysed by gas chromatography after clean-up and concentration. The optimal extraction conditions selected for pressure, temperature, extraction time and nature of solvent were respectively 14 MPa, 160 °C, 24 min and hexane/acetone (1/1 *v*/*v*). The analytical procedure was validated by comparing predicted and experimental values of sediment samples and by analysing standard reference material. The validated method was then applied to establish a depth profile contamination in the sediment of the Deûle River in northern France.

14/03628 Impact of oxidation and biodegradation on the most commonly used polycyclic aromatic hydrocarbon (PAH) diagnostic ratios: implications for the source identifications

Biache, C. *et al. Journal of Hazardous Materials*, 2014, 267, 31–39.

Based on the isomer stability during their formation, polycyclic aromatic hydrocarbon (PAH) diagnostic ratios have been extensively used to determine PAH contamination origin. Nevertheless, it is known that these isomers do not present the same physicochemical properties and that reactions occurring during the transport from an atmospheric source induce changes in the diagnostic ratios. Yet, little is known about reactions occurring in soils contaminated by other sources such as coal tar and coal. Innovative batch experiments of abiotic oxidation and microbial incubations were performed to discriminate independently the influence of these two major processes occurring in soils on the diagnostic ratios of major PAH sources. Three samples were studied, a coking plant soil and two major PAH sources in this soil, namely coal and coal tar. The combustion signature of the coking plant soil showed the major influence of coal tar in the soil sample composition. Some of these ratios were drastically affected by oxidation and biodegradation processes inducing a change in the source signature. The coal tar signature changed to petrogenic source after oxidation with the anthracene/(anthracene + phenanthrene) ratio. According to this ratio, the initial petrogenic signature of the coal changed to a combustion signature after the biodegradation experiment.

14/03629 Mathematical modeling of hydrocarbon emissions from oil film for different fuels

Karamangil, M. I. *et al. Fuel*, 2014, 115, 818–825.

Oil film on the inner surface of an engine's cylinder liner is one of the major sources of the vehicle hydrocarbon (HC) emissions as fuel vapour is absorbed by the oil film under high pressure and then released after late expansion stroke when the pressure is low. This process is extensively affected by type of the fuel and lubricating oil. In this theoretical study, the effect of different engine parameters on oil film HC emissions for various fuels, such as iso-octane, methanol, ethanol, liquid petroleum gas (LPG) and methane, is investigated. The results show that fewer HCs are released from the oil film when using gaseous fuels, such as LPG and methane, than when using liquid fuels. The fuels can be ranked according to their effect (from greatest to least) on HC emissions as follows: iso-octane, methanol, ethanol, LPG and methane. The most important parameters affecting the HC absorption/release mechanism are found to be Henry's coefficient and the diffusion coefficient. As interaction time of oil film–fuel vapour was longer at low engine speeds, the quantities of HC absorbed/desorbed increased. The quantities of HC absorbed/desorbed increased with increasing inlet pressure and compression ratio.

14/03630 Measurement of fugitive volatile organic compound emissions from a petrochemical tank farm using open-path Fourier transform infrared spectrometry

Wu, C.-F. *et al. Atmospheric Environment*, 2014, 82, 335–342.

Fugitive emission of air pollutants is conventionally estimated based on standard emission factors. The vertical radial plume mapping (VRPM) technique, as described in the US EPA OTM-10, is designed to measure emission flux by directly monitoring the concentration of the plume crossing a vertical plane downwind of the site of interest. This paper describes the evaluation results of implementing VRPM in a complex industrial setting (a petrochemical tank farm). The vertical plane was constructed from five retroreflectors and an open-path Fourier transform infrared spectrometer. The VRPM configuration was approximately 189.2 m in width by 30.7 m in height. In the accompanying tracer gas experiment, the bias of the VRPM estimate was less than 2% and its 95% confidence interval contained the true release rate. Emission estimates of the target volatile organic compounds (benzene, m-xylene, o-xylene, p-xylene and toluene) ranged from 0.86 to 2.18 $g\,s^{-1}$ during the 14-day field campaign, while estimates based on the standard emission factors were one order of magnitude lower, possibly leading to an underestimation of the impact of these fugitive emissions on air quality and human health. It was also demonstrated that a simplified three-beam geometry (i.e. without one-dimensional scanning lines) resulted in higher uncertainties in the emission estimates.

14/03631 Methane emissions of energy activities in China 1980–2007

Zhang, B. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 11–21.

As the largest CH_4 emitter, China produces CH_4 at an increasing rate, especially from its energy activities. Presented in this paper is a detailed inventory and analysis of CH_4 emissions from energy activities in China from 1980 to 2007 covering all the significant sources. The total energy-related CH_4 emissions in China tripled during the period with an average annual increase rate of 4.7% and reached 21,943.1 Gg in 2007, 2.4 times of that in USA. As the largest emission source, coal mining, increased its share from 69.2% (4559.5 Gg) in 1980 to 85.8% (18,825.5 Gg) in 2007; The second biggest source was fuel combustion, mainly bio-fuel combustion (2370.3 Gg in 2007); oil and natural gas system leakage was a minor source but at a rapidly increasing rate. This transient emission structure is quite different from the steady structure of the USA, which is dominated by the fugitive emissions from natural gas and oil systems. According to the lower IPCC global warming potential, the annual energy-related CH_4 emissions were equivalent to

9.1–11.7% of China's energy-related CO_2 emissions, amounting to 548.6 Mt CO_2-eq in 2007 which is greater than the nationwide gross CO_2 emissions in many developed countries.

14/03632 Particulate associated polycyclic aromatic hydrocarbon exhaust emissions from a portable power generator fueled with three different fuels – a comparison between petroleum diesel and two biodiesels

Sadiktsis, I. *et al. Fuel*, 2014, 115, 573–580.

The fuel impact on the emission of more than 40 particulate associated polycyclic aromatic hydrocarbons (PAHs) in the molecular weight range 178–302 Da were investigated. The fuels; neat diesel (EN 590), rape seed methyl ester (B100) and a 30% w/w blend thereof (B30) were tested on a portable power generator without any exhaust after-treatment. Gaseous emissions of carbon monoxide (CO), hydrocarbons (HC) and nitrogen oxides (NO_x) were measured along with particulate emissions and its size distribution for the different fuels. Collected diesel particles were extracted using pressurized fluid extraction and analysed using an online hyphenated liquid chromatography–gas chromatography–mass spectrometry system. The neat B100 and the B30 fuel produced less CO and total PAHs while the emissions of NO_x and particulate matter increased compared with petroleum diesel fuel per kW h. The reduction of PAH emissions of the alternative diesel fuels were 36% and 70% for B30 and B100, respectively. While the PAH profiles for the neat diesel fuel and B30 were similar, the profile of B100 differed in the sense that the emission contained a higher percentage of PAHs with higher molecular weights. The emission of these PAHs was however larger using the neat diesel fuel with the exception for some of these higher molecular weight PAHs of which there was an increased emission using B100. Thermogravimetric analysis revealed that the collected particles from B100 contained a substantial amount of volatile components. A mass spectrometric full scan analysis suggests that these volatile components are in fact unburned or partially burned fuel constituents. It is concluded that the particles originating from biodiesel combustion might be very different from those originating from petroleum diesel combustion which places new demands on the development of measurement methodologies originally developed for particulate emissions from petroleum-based fuels.

14/03633 Spatial and seasonal variability of measured anthropogenic non-methane hydrocarbons in urban atmospheres: implication on emission ratios

Boynard, A. *et al. Atmospheric Environment*, 2014, 82, 258–267.

Continuous measurements of a wide range of non-methane hydrocarbons (NMHC) have been performed since 2001 in Paris megacity and three French medium-sized cities (Grenoble, Marseille and Strasbourg). After a careful verification of the data measured, the ambient concentrations are used to analyse the spatial and seasonal variability of the anthropogenic NMHC and determine the present NMHC emission ratios relative to acetylene, a useful metric to evaluate and constraint emission inventories. The authors show that NMHC urban composition is consistent between all cities with no industrial influence and characteristic of the urban emission mixtures, which are mostly dominated by vehicle exhaust emissions. In winter, the urban NMHC composition generally shows an enhancement in combustion-derived products (alkenes, acetylene), C2–C3 alkanes and benzene, which presumes seasonal changes in emission ratio values. Present emission ratios of NMHC relative to acetylene are determined in Paris and Strasbourg both in summer and winter. They generally compare within a factor of two except for C7–C9 aromatics in Paris. On a seasonal basis, summertime emission ratios are three times higher than wintertime ones while they stay constant for combustion derived product (alkenes) and benzene. The unburned gasoline fraction (alkanes and C7–C9 aromatics) shows the maximum difference up to a factor of seven. These findings suggest that the emission ratios reflect seasonal changes in emissions and can be a useful metric to constraint temporally resolved emission inventories at different time of the year.

Life cycle analysis

14/03634 An oil palm-based biorefinery concept for cellulosic ethanol and phytochemicals production: sustainability evaluation using exergetic life cycle assessment

Ofori-Boateng, C. and Lee, K. T. *Applied Thermal Engineering*, 2014, 62, (1), 90–104.

In this study, thermo-environmental sustainability of an oil palm-based biorefinery concept for the co-production of cellulosic ethanol and phytochemicals from oil palm fronds (OPFs) was evaluated based on exergetic life cycle assessment (ExLCA). For the production of 1 tonne bioethanol, the exergy content of oil palm seeds was upgraded from 236 to 77,999 MJ during the farming process for OPFs' production. Again, the high exergy content of the OPFs was degraded by about 62.02% and 98.36% when they were converted into cellulosic ethanol and phenolic compounds, respectively. With a total exergy destruction of about 958,606 MJ (internal) and 120,491 MJ (external or exergy of wastes), the biorefinery recorded an overall exergy efficiency and thermodynamic sustainability index (TSI) of about 59.05% and 2.44 per tonne of OPFs' bioethanol, respectively. Due to the use of fossil fuels, pesticides, fertilizers and other toxic chemicals during the production, the global warming potential (GWP = 2265.69 kg CO_2 eq.), acidification potential (AP = 355.34 kg SO_2 eq.) and human toxicity potential (HTP = 142.79 kg DCB eq.) were the most significant environmental impact categories for a tonne of bioethanol produced in the biorefinery. The simultaneous saccharification and fermentation unit emerged as the most exergetically efficient (89.66%), thermodynamically sustainable (TSI = 9.67) and environmentally friendly (6.59% of total GWP) production system.

14/03635 Development of an optimum design program (SUSB-OPTIMUM) for the life cycle CO_2 assessment of an apartment house in Korea

Roh, S. *et al. Building and Environment*, 2014, 73, 40–54.

The aim of this study was to develop and evaluate the applicability of an optimum design program (SUSB-OPTIMUM) for the life cycle CO_2 assessment of an apartment house that can be readily utilized during the planning and design phases. For this purpose, a database containing information on the CO_2-reducing performance and the cost of environmentally friendly construction technologies that are applicable to apartment houses was constructed, and an interpretation program was built based on a simplified technique for assessing the life cycle CO_2 emissions of an apartment house and the unit costs based on the inter-industry relation table. In addition, by integrating the interpretation program with an optimum design system based on an evolutionary algorithm, an optimum design system was created to compute the optimal solution with regard to the life cycle CO_2 emissions and economic feasibility of apartment buildings. The applicability of the optimum design program developed in this study was evaluated by means of a case study. The case study results revealed that it is possible to compute the optimum combination of environmentally-friendly construction technologies, as well as the quantity of life cycle CO_2 emissions and costs in order to reach a CO_2 emissions target at a cost comparable to that of a standard apartment house.

14/03636 Forest biomass supply chains in Ireland: a life cycle assessment of GHG emissions and primary energy balances

Murphy, F. *et al. Applied Energy*, 2014, 116, 1–8.

The demand for wood for energy production in Ireland is predicted to double from 1.5 million m^3 overbark (OB) in 2011 to 3 million m^3 OB by 2020. There is a large potential for additional biomass recovery for energetic purposes from both thinning forest stands and by harvesting of tops and branches, and stumps. This study builds on research within the wood-for-energy concept in Ireland by analysing the energy requirements and greenhouse gas (GHG) emissions associated with thinning, residue bundling and stump removal for energy purposes. To date there have been no studies on harvesting of residues and stumps in terms of energy balances and greenhouse gas emissions across the life cycle in Ireland. The results of the analysis on wood energy supply chains highlights transport as the most energy and GHG emissions intensive step in the life cycle. This finding illustrates importance of localized production and use of forest biomass. Production of wood chip, and shredded bundles and stumps, compares favourably with both other sources of biomass in Ireland and fossil fuels.

14/03637 Integrated well-to-wheel assessment of biofuels combining energy and emission LCA and welfare economic cost benefit analysis

Møller, F. *et al. Biomass and Bioenergy*, 2014, 60, 41–49.

The present study integrates material-based life cycle analysis (LCA) with welfare economic cost benefit analysis (CBA) to evaluate resource and environmental consequences as well as welfare consequences for society of introducing biofuels in the Danish road transport sector. The integrated method focus on fossil energy consumption, CO_2 emissions and total welfare economic changes within the whole LCA flow chain comprising both production of biomass and subsequent conversion into biofuel and combustion in vehicles. With regard to consequences for fossil energy consumption a global delimitation is used whereas only CO_2 emissions and welfare economic consequences within Danish borders are included in the analysis. Consequently, calculated emission and welfare economic consequences can be interpreted as the consequences for Denmark of producing and using biofuels from biomass grown on Danish farm land. The method is applied with regard to production of rape diesel (rape methyl ester, RME), first-generation ethanol from wheat and second-generation ethanol based on straw.

Advantages and disadvantages of the LCA-based material flow approach and the welfare economic-based CBA approach are discussed. The influence of uncertainties on the results is evaluated illustrating the importance of paying attention to assumptions with regard to substitution of other products and resources and with regard to their relative prices.

14/03638 Internalizing land use impacts for life cycle cost analysis of energy systems: a case of California's photovoltaic implementation
Lakhani, R. *et al. Applied Energy*, 2014, 116, 253–259.
Solar photovoltaic (PV) is a rapidly growing electricity generation technology. The increasing penetration of this technology is facilitated by incentives and public policy support that are being offered by various jurisdictions. There are various options for installing PV systems, rooftop and ground mounted systems being the two common options. The choice between these options has been complicated by the trade-offs between cost and land use impacts. This study develops a framework that can be used to highlight and quantify the trade-offs between costs and land using life cycle costs (LCC), life cycle land use footprints and consequent land use impacts across various options of implementing PV systems. The study demonstrates the application of the framework using a hypothetical case study of implementing various options of PV systems in California. The results indicate that at 14.2 ¢/kWh, the utility-scale ground mounted option has the lowest LCC compared to residential and commercial rooftop mounted options. However, the utility-scale option has the highest land use footprint and land use impacts. The monitory value of the land use impacts from implementing utility scale ground mounted systems depends primarily on the type of associated ecosystems and the value people place on them. For the rooftop option in this case study to be preferred to the ground mounted option, the value of land use impacts would have to increase significantly.

14/03639 Life cycle assessment (LCA) and life cycle energy analysis (LCEA) of buildings and the building sector: a review
Cabeza, L. F. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 394–416.
This review summarizes and organizes the literature on life cycle assessment (LCA), life cycle energy analysis (LCEA) and life cycle cost analysis studies carried out for environmental evaluation of buildings and building-related industries and sectors (including construction products, construction systems, buildings and civil engineering constructions). The review shows that most LCA and LCEA are carried out in what is shown as 'exemplary buildings', that is, buildings that have been designed and constructed as low-energy buildings, but there are very few studies on 'traditional buildings', that is, buildings such as those mostly found in cities. Similarly, most studies are carried out in urban areas, while rural areas are not well represented in the literature. Finally, studies are not equally distributed around the world.

14/03640 Life cycle assessment of a hemp concrete wall: impact of thickness and coating
Pretot, S. *et al. Building and Environment*, 2014, 72, 223–231.
In a context of sustainable development and energy sparing, a life cycle assessment (LCA) may be useful to make good choices. Thus, this study concerns the LCA of an environmentally friendly material used for building construction: hemp concrete. The functional unit is first defined per square metre, such that the wall may provide the function of bearing wall and its thermal performance is described by a thermal resistance of 2.78 m^2 K/W. The results then showed that the production phase of raw materials is mainly responsible for the environmental impact of the wall, mostly due to the binder production. It was also shown that, compared to traditional construction materials, hemp concrete has a low impact on environment. Moreover, hemp concrete contributes to reduce climate change as photosynthesis-mediated carbon sequestration and carbonation serve to reduce atmospheric carbon dioxide. A sensitivity analysis is performed on three criteria: wall thickness, renewal of coatings and compounds of the indoor coating. The results show that environmental indicators evolve with wall thickness, except for the climate change indicator. It improves with thickness due to carbon sequestration and carbonation. Moreover the increase in the wall's thermal resistance with wall thickness is not taken into account in such an LCA performed at the material level. The renewal of coating slightly impacts the environmental indicator for small numbers of renewals but it leads to negative effects if they are too numerous. It appears that hemp-lime coating has a greater impact than sand-lime coating as it embeds more binder.

14/03641 Optimization of a residential solar combisystem for minimum life cycle cost, energy use and exergy destroyed
Hin, J. N. C. and Zmeureanu, R. *Solar Energy*, 2014, 100, 102–113.
This paper presents the optimization of a model of a solar combisystem in an energy efficient house in Montreal, Canada. A hybrid particle swarm and Hook–Jeeves generalized pattern search algorithm is used to minimize the life cycle cost, energy use and exergy destroyed of the combisystem. The results presented include four different optimal configurations depending on the objective function used. The optimizations were able to reduce, compared with the base case combisystem, the life cycle cost of the combisystem by 19%, the life cycle energy use by 34%, the life cycle exergy destroyed by 33% and 24% using the technical boundary and physical boundary, respectively. Due to the high cost of the solar collector technologies and the low price of electricity in Quebec, none of the optimal configurations have acceptable financial payback periods. However, they all have energy payback times between 5.8 and 6.6 years. The use of technical boundary in the exergy analysis favours the use of electricity over solar energy due to the low exergy efficiency of the solar collectors. The use of the physical boundary, on the other hand, favours the use of solar energy over electricity, and all of the combisystem configurations have exergy payback times between 4.2 and 6.3 years.

14/03642 Scope-based carbon footprint analysis of U.S. residential and commercial buildings: an input–output hybrid life cycle assessment approach
Onat, N. C. *et al. Building and Environment*, 2014, 72, 53–62.
Analysing building-related carbon emissions remains as one of the most increasing interests in sustainability research. While majority of carbon footprint studies addressing buildings differ in system boundaries, scopes, greenhouse gases and methodology selected, the increasing number of carbon footprint reports in response to legal and business demand paved the way for worldwide acceptance and adoption of the Greenhouse Gas Protocol set by the World Resources Institute (WRI) and World Business Council for Sustainable Development. Current research is an important attempt to quantify the carbon footprint of the US residential and commercial buildings in accordance with carbon accounting standards and scope set by the WRI, in which all possible indirect emissions are also considered. Emissions through the construction, use, and disposal phases were calculated for the benchmark year 2002 by using a comprehensive hybrid economic input–output life cycle analysis. The results indicate that emissions from direct purchases of electricity (scope 2) with 48% have the highest carbon footprint in the US buildings. Indirect emissions (scope 3) with 32% are greater than direct emissions (scope 1) with 20.4%. Commuting is the most influential activity among the scope 3 emissions with more than 10% of the carbon footprint of the US buildings overall. Construction supply chain is another important contributor to the US building's carbon footprint with 6% share. Use phase emissions are found to be the highest with 91% of the total emissions through all of the life cycle phases of the US buildings.

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Supplies, policy, economics, forecasts

14/03643 A spatial multi-period long-term energy planning model: a case study of the Greek power system
Koltsaklis, N. E. *et al. Applied Energy*, 2014, 115, 456–482.
This paper presents a mixed-integer linear programming model for the optimal long-term energy planning of a (national) power generation system. In order to capture more accurately the spatial and technical characteristics of the problem, the underlying geographical area (country) is divided into a number of individual networks that interact with each other. The proposed model determines the optimal planning of the power generation system, the selection of the power generation technologies, the type of fuels and the plant locations so as to meet the expected electricity demand, while satisfying environmental constraints in terms of CO_2 emissions. Furthermore, the suggested model determines the electricity imports from neighbouring countries, the electricity transmission as well as the transportation of primary energy resources between domestic networks. A real case study concerning the Greek energy planning problem demonstrates the applicability of the proposed approach, which can provide policy makers with a systematic computer-aided tool to analyse various scenarios and technology options. Finally, a sensitivity analysis was conducted in order to capture the influence of some key parameters such as electricity demand, natural gas and CO_2 emission price as well as wind power investment cost.

14/03644 Economics and design of balancing power markets in Germany

Müsgens, F. *et al. International Journal of Electrical Power & Energy Systems*, 2014, 55, 392–401.

This paper analyses the economic fundamentals that govern market design and behaviour in German balancing power markets. Then, partly based on theoretical work from an earlier study, the authors illustrate the role of the scoring and the settlement rule as key elements of the market design. With sufficiently competitive markets, a settlement rule based on uniform pricing ensures efficient energy call in the balancing power market. A scoring rule based on capacity prices only ensures an efficient production schedule. Thus, both rules together with rational bidding ensure simultaneous efficiency on the balancing power market and the wholesale electricity market.

14/03645 Engineering economic assessment of whole-house residential wood heating in New York

Loughlin, D. H. and Dodder, R. S. *Biomass and Bioenergy*, 2014, 60, 79–87.

Wood devices increasingly are being used for residential space heating in New York, USA. Motivations include avoiding high and variable fuel costs, promoting energy independence, mitigating climate change and stimulating local economic development. In this study, the influence of fuel prices, device costs and device efficiencies on heating costs was examined. Lifetime costs of alternative heating technologies were calculated for a house in Syracuse, New York. Calculations were repeated to explore discount rates and fuel price projections. Combinations of wood price and device cost and efficiency were identified at which wood is competitive with other fuels. The results suggest that fuel costs drive competitiveness more than capital and installation costs. At typical wood prices, natural gas often is the least expensive option. Many rural areas do not have access to gas, however, and high-efficiency wood-heating devices can be very competitive with heat pumps, propane boilers, and fuel-oil boilers. Availability of low-cost or on-site wood can make wood the least expensive option. However, even 'free' wood is not free when the equipment, labour, space and time required are considered. Furthermore, efficiencies of wood devices and their pollutant emissions can differ greatly. High emission rates have led to restrictions on use of specific wood-heating devices in some locations. Improved information and tools should be available to consumers for evaluating the suitability of wood heating for their particular situations. The work presented here is an example of such information.

14/03646 Existing buildings – users, renovations and energy policy

Gram-Hanssen, K. *Renewable Energy*, 2014, 61, 136–140.

This paper deals with the energy consumption of existing owner-occupied detached houses and the question of how they can be energy renovated. Data on the age of the Danish housing stock, and its energy consumption are presented. Research on the potential for energy reductions in the Danish housing sector is discussed, and it is shown that there is a huge potential for reductions. It is a well-known problem that even if there are relevant technical means and even if it is economically feasible, the majority of house owners do not energy-renovate their homes. This paper intends to address what can be done to solve this problem. The paper draws on different sources of why, when, and how, people do not energy-renovate their homes. These results are then compared and discussed together with a presentation and discussion of the Danish policy measures aimed at encouraging people to energy-renovate their homes. These policy measures include building regulations, energy tax and different types of incentives and information dissemination. The conclusion calls for new and innovative policy measures to cope with the realities of renovations of owner-occupied houses and how energy efficiency improvement could be part of that.

14/03647 Implementing a biofuel economy in the EU: lessons from the SUSTOIL project and future perspectives for next generation biofuels

De Lucia, C. and Bartlett, M. *Renewable and Sustainable Energy Reviews*, 2014, 29, 22–30.

The aim of this paper is to illustrate the main economic and environmental [greenhouse gas (GHG) emissions reduction] effects of implementing a biofuel economy and to discuss the potential of establishing advanced biofuels in the European Union (EU). The study is based on the recently completed EU FP7 SUSTOIL research project. The main question addressed is the EU policy objective of achieving 20% GHG emissions reduction using 20% of renewables by the year 2020. To contribute to the achievement of this policy, the authors run and execute, through a computable general equilibrium model, a simulation experiment of implementing a bio-based economy using biorefineries in the production process. The main results suggest that: (a) biorefineries working from oil seeds and their by-products will lead to a large increase in the amount of this crop (grown particularly in eastern Europe); (b) this increase will be accompanied by a decrease in sectoral gross domestic product in several other areas; (c) oil and electricity prices will generally fall in across the EU with a particularly notable trend in eastern Europe; and (d) a reduction in carbon emissions is achieved but this will be insufficient to meet the EU's 20% target. This latter result would suggest speeding up the technological process towards the use of next-generation biofuels in the EU. Furthermore, these results advocate a leading role expected to be played by eastern EU countries over the coming years. The expected increase in the cultivation of energy crops could conflict with the availability of land for food crops. The potential for establishing next-generation biofuels in the EU with adequate support policies would be essential for guaranteeing energy and food security in the long run.

14/03648 Indirect land use change – help beyond the hype?

Finkbeiner, M. *Biomass and Bioenergy*, 2014, 62, 218–221.

The 'food vs fuel' debate inspired the concept of indirect land use change (iLUC). Greenhouse gas emission factors for iLUC are proposed for inclusion into carbon footprints (CF) of biofuels. The range of published iLUC values is enormous: from about 200% below, up to 1700% above the CF values of fossil fuels. From the perspective of life cycle assessment (LCA) and CF science, single iLUC factors are currently more representative for the approach or model used than for the crop or biofuel assessed. The scientific robustness is not sufficient for political and corporate decision making. None of the relevant international standards of LCA or CF require the inclusion of iLUC. The iLUC concept deserves credit for raising awareness of a relevant problem but it is not the solution. Science and policy should focus on proactive real world mitigation of iLUC rather than reactive and theoretical iLUC factors.

14/03649 Integrated waste management as a mean to promote renewable energy

Eriksson, O. *et al. Renewable Energy*, 2014, 61, 38–42.

The effective management of municipal solid waste is an efficient method to both increase resource efficiency (material and energy recovery instead of landfill disposal) and to replace fossil fuels with renewable energy sources (waste is renewable in itself to a large extent as it contains paper, wood, food waste, etc.). This paper presents the general outline and results from a system study of future waste management. In the study, a multifunctional waste management system integrated with local energy systems for district heating and electricity, wastewater treatment, agriculture and vehicle fuel production is investigated with respect to environmental impact and financial economy. Different waste technologies, as well as management strategies, have been tested. The treatment is facilitated through advanced sorting, efficient treatment facilities and upgrading of output products. The tools used are the ORWARE model for the waste management system and the MARTES model for the district heating system. The results for potential global warming are used as an indicator for renewable energy. In all future scenarios and for all management strategies, a net saving of CO_2 is accomplished. Compared to a future reference, the financial costs will be higher or lower depending on the management strategy used.

14/03650 On energy consumption and GDP studies; a meta-analysis of the last two decades

Menegaki, A. N. *Renewable and Sustainable Energy Reviews*, 2014, 29, 31–36.

The relationship between energy consumption and gross domestic product (GDP) growth has been intensely examined in multiple frameworks set by various methods and countries. This paper is a meta-analysis of 51 studies published in the last two decades, with worldwide data since 1949, on the relationship between energy consumption and GDP growth. The aim is to systemize some of the factors that cause the variation of results in these studies. The results yield evidence that the long run elasticity of GDP growth with respect to energy consumption is not independent of the method employed for cointegration, the data type and the inclusion of variables such as the price level or capital in the cointegration equation. Also 1% increase in capital, increases the elasticity of GDP with respect to energy consumption by 0.85%.

14/03651 Pricing carbon in the U.S.: a model-based analysis of power-sector-only approaches

McKibbin, W. J. *et al. Resource and Energy Economics*, 2014, 36, (1), 130–150.

One proposed climate policy is a 'power-sector-only' approach that would focus exclusively on controlling carbon dioxide emissions from electricity generation. This paper uses an intertemporal computable general equilibrium model of the world economy called G-Cubed to compare a power-sector-only climate policy with two alternative economy-wide measures that either: (1) place the same price on carbon or (2) achieve the same cumulative emissions reduction as the programme limited to the power sector. It was found that the power-

sector-only approach requires a carbon price to electric utilities that is almost twice the economy-wide carbon price that would achieve the same cumulative emissions. In addition, it was found that the power-sector-only policy does not produce offsetting increases in emissions in other sectors or other countries. Rather, domestic carbon emissions outside the power sector fall slightly relative to baseline as higher electricity prices slow overall economic activity. Global emissions leakage is negligible as the price of oil in other currencies changes little. All three policies reduce investment in the capital-intensive energy sector, which lowers imports of durable goods and strengthens the US terms of trade.

14/03652 Regulating land development in a natural disaster-prone area: the roles of building codes
Wang, C. *Resource and Energy Economics*, 2014, 36, (1), 209–228.
Implementing mandatory building codes is a major approach to preparing for natural disasters. Using a simple hybrid model which considers expected utility and spatial equilibrium, this paper analyses the roles as self-insurance and self-protection played by building codes for regulating land development in a disaster-prone area. Positive externalities of self-insurance and self-protection justify the implementation of mandatory building codes. The net benefits of building codes are capitalized into land rents which, in turn, require responses in the design of optimal codes. Through impacting land market, community-wide socioeconomic characteristics of the area such as population, wage, and land area share of the risky region are found to have effects on the optimal levels of expenditure on self-insurance and self-protection. It is shown that consumer preferences and production functions for self-insurance and self-protection determine the signs of such effects which are reinforced or offset by competition for locations in the land market. Effects from changes in productivity levels and risk structure are also described.

14/03653 Sustainable economy development and transition of fuel and energy in Lithuania after integration into the European Union
Gaigalis, V. and Skema, R. *Renewable and Sustainable Energy Reviews*, 2014, 29, 719–733.
This paper describes the sustainable development of the Lithuanian economy and transition of fuel and energy after the integration of Lithuania into the European Union (EU), covering the period 2004–2012. In 2004–2008, Lithuanian gross domestic product (GDP) increased approximately 1.8 times and Lithuania was one of the most rapidly developing countries in the EU. The average of the yearly growth rate of GDP was 7.1%. In 2008 GDP growth rate decreased to 2.9% whereas in 2009 – down to –14.8% (the consequences of the global financial crisis). In 2009–2012 Lithuanian economy recovered and GDP reached the volume before the crisis. GDP per capita at current prices in the period 2004–2012 increased about twice from 18,300 to 37,500 LTL (1 LTL = €0.2896). In Lithuania 70–80% of electricity in 2004–2009 was produced by the Ignalina Nuclear Power Plant (INPP). The indigenous and renewable energy sources (RES) in 2009 comprised 14.7% of gross inland energy consumption. At the end of 2009 the INPP was closed as it was unsafe and the structure of gross inland fuel and energy consumption changed radically. The sector of RES became the driving force of the country's economy. In the analysis, the growth rate and the index of GDP in Lithuania are given. The composition and tendencies of changes of gross inland and the final energy consumption are highlighted. The share of the RES in gross inland energy consumption is indicated. Final fuel and energy consumption by different energy sources and various consumer groups is analysed. The indices of energy intensity and labour productivity in different spheres of economy are presented. The environmental pollution indicators, emissions of greenhouse gas and other air pollutants by all kinds of economic activities are analysed.

14/03654 The research on energy in Spain: a scientometric approach
Montoya, F. G. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 173–183.
This work describes the features of the contributions made by the Spanish institutions to the specialized literature in the energy field in the period 1957–2012. The source considered has been the Scopus Elsevier database, together with bibliometric analysis techniques. All items provided by Scopus have been taken into account in the analysis (journal papers, conference proceedings, etc.). The results of this work show that the Spanish contribution is more than significant in the light of the obtained data, with the following keywords being the most used terms: power, energy, system, wind and solar. Different aspects of the publications are analysed, such as publication type, field, language, subcategory and journal type, as well as the keyword occurrence frequency. The contributions are geographically and institutionally broken down, with Madrid and Catalonia the main research regions. At an international level, Spain mainly works jointly with France, USA, Germany and the UK. The most active categories in the energy field are engineering, materials science and chemistry. It can be stated that Spanish research enjoys good health and is an important and relevant player in the international scientific scene.

Energy conservation

14/03655 A hydrothermal model to assess the impact of green walls on urban microclimate and building energy consumption
Malys, L. *et al. Building and Environment*, 2014, 73, 187–197.
Covering a building envelope with vegetation provides a solution capable of mitigating the urban heat island phenomenon and its impact on the energy consumption of buildings. Simulation tools to assess the efficiency of such a solution are lacking, especially for green walls. The present research aims to offer a hydrothermal model of green walls and green roofs for implementation in the urban microclimate simulation software SOLENE-Microclimate. To this end, a fast, efficient coupled heat–mass transfer model has been developed. Simulation results are compared with experimental data obtained from the LEEA Laboratory in Geneva, Switzerland, for three green wall samples. Aside from the level of uncertainty found for the evapotranspiration calculation, these results confirm that the model accurately characterizes the temperature evolution of all three prototypes. Results also show good correlation between measured and simulated temperatures. The model is indeed able to reproduce water stress and characterize various types of living walls.

14/03656 A simulation-based decision model for designing contract period in building energy performance contracting
Deng, Q. *et al. Building and Environment*, 2014, 71, 71–80.
This paper presents a simulation-based decision model for contract period determination in energy performance contracting (EPC). The model attempts to assist the energy service companies (ESCOs) on how long the contract period should be to balance the bidding competitiveness and the potential revenue loss. The uncertainties within the energy efficiency investment and the energy cost savings as return are addressed by stochastic processes, taking the maintenance and savings performance variations and the energy price fluctuations into account. Considering both the contract period and the energy cost savings guarantee, a framework is proposed to identify the profit sharing in EPC for both the owners and the ESCOs. An optimization model is derived accordingly, and the balanced length of the contract period is then reached. Finally, a campus case is presented to verify the applicability of the proposed model. The method can be used by industry practitioners as a decision support tool for contract period design, and is worth popularizing in other performance-based projects.

14/03657 An estimation model for the heating and cooling demand of a residential building with a different envelope design using the finite element method
Koo, C. *et al. Applied Energy*, 2014, 115, 205–215.
Building envelope design is considered one of the typical energy-saving techniques. The building envelope serves as the physical separator between a building's interior and exterior environment so as to maintain indoor thermal comfort. To achieve building sustainability, this research aims to develop an estimation model for the heating and cooling demand of a residential building with a different envelope design using the finite element method. This research was conducted in three steps: (i) selection of building envelope design elements affecting the heating and cooling demand of a multi-family housing unit; (ii) establishment of a standard database for the heating and cooling demand by building envelope design through energy simulation and (iii) implementation of the finite element method for estimating the heating and cooling demand by building envelope design. The proposed model was validated compared to the simulation results and the actual data. Regarding the comparison with the simulation results, the average error rate for the heating and cooling demand was determined to be 1.09% and 6.61%, respectively. Also, regarding the comparison with the actual data, the average error rate for the heating and cooling consumption was determined to be 4.95% and 5.77%, respectively. The proposed model could allow an architect or a construction manager to easily and accurately estimate the heating and cooling demand of a residential building with a different envelope design in the early design phase. It could also be useful for contractors in a competitive bidding process to analyse the alternatives.

14/03658 An investigation of geothermal energy applications and assisted air-conditioning system for energy conservation analysis
Tsai, J.-H. *et al. Geothermics*, 2014, 50, 220–226.

This study used the Sea Gaia Spring Hotel in Wanli, Taiwan, where geothermal water at 90–100 °C is used as a hot spring, as a case study to analyse the effect of geothermally assisted air-conditioning systems. The results of analysis showed that the total electric energy consumption in the building was reduced by 26%, the electric energy consumed by the air-conditioned heating system of the building was reduced by 54%, and the electric energy consumed by the air-host was reduced by 66.5%.

14/03659 Energy performance enhancement of Hong Kong International Airport through chilled water system integration and control optimization

Sun, Y. *et al. Applied Thermal Engineering*, 2013, 60, (1–2), 303–315.

The poor energy performance of building systems is often observed, especially under off-design conditions (i.e. at low part load ratios). In order to overcome such problems, most of existing methods are developed merely considering a single system or building. Unlike them, a method integrating the chilled water systems in the neighbouring buildings is proposed here to enhance the overall energy performance of the Hong Kong International Airport. The system integration allows the excessive cooling from one building to be delivered to another. In addition, one 1000 RT chiller is relocated from Terminal 2 to Terminal 1. After the system integration and chiller relocation, three different-sized chillers can be selected to satisfy the overall cooling load with higher part load ratios. Meanwhile, the control optimizations of chillers and seawater pumps also contribute to the system energy performance improvement. With limited investment cost and easy implementation, the proposed method and the control optimization significantly enhance the airport's system energy performance. The direct field data comparison demonstrated the average chiller plant coefficient of performance value is improved by 5.93%. The simulated case studies indicated an annual energy saving about 4.70 M kWh is achievable.

14/03660 Experiences from nine passive houses in Sweden – indoor thermal environment and energy use

Rohdin, P. *et al. Building and Environment*, 2014, 71, 176–185.

This paper presents experiences from a recently built area with passive houses in Linköping, Sweden and compares them with conventional buildings, mainly from an indoor environment perspective, but also based on energy use. The built area consists of 39 recently constructed terraced houses, of which nine are built according to the passive house standard. The aspects of thermal comfort as well as local discomfort are studied. The methodology is based on on-site measurements and two types of simulations – computational fluid dynamics and building energy simulation. In addition, a post-occupancy evaluation was made using a standardized questionnaire to relate the occupant's perception of the indoor environment a year after the buildings were completed. The thermal comfort for these newly built passive houses is well within the limits in the local building code. However, some interesting findings related to local comfort such as cold floors are found in the post-occupancy evaluation as well as in the predictions. The occupants of the passive houses experience cold floors to a higher degree than in the conventional buildings. It was also shown that there are a higher number of complaints related to high temperatures during summer in the passive houses. It is worth noting that the buildings do not have external shading installed by default. The effect of varying temperatures was also observed in the passive houses to a higher degree than in the more conventional buildings, especially related to cooking and other heat-generating activities, which is normal in a more well insulated and airtight building.

14/03661 Study of gas insulated substation and its comparison with air insulated substation

Nagarsheth, R. and Singh, S. *International Journal of Electrical Power & Energy Systems*, 2014, 55, 481–485.

This paper evaluates the two types of substation, namely the air-insulated substation (AIS) and the gas-insulated substation (GIS) on the basis of the life-cycle cost method, reliability and environmental effects. The problems of very fast transient oscillations faced in GIS and their possible solutions. It substantiates and supports the use of GIS over AIS with an in depth analysis. In the end, hybrid GIS has been proposed as a solution to overcome drawbacks of both AIS and GIS and to use the advantages of both in a single system for the best results.

14/03662 Sustainable bus transports through less detailed contracts

Lidestam, H. *Renewable Energy*, 2014, 61, 141–146.

The purpose of this paper is to investigate both environmental effects and cost effects of using less specified contracts regarding bus sizes in public bus transports. The process of choosing the best bid in the public procurement of bus transports is easier if the demands of the qualifications are well specified and detailed. On the other hand, detailed contracts can force the entrepreneurs to use less environmentally friendly and uneconomical alternatives. A mathematical model with binary variables is developed to evaluate the environmental and the economic effects of more optimized bus sizes. Computational results from a bus service provider are reported. The results of the model indicate that the emissions decrease considerably by using less detailed contracts. The results of a subcase indicate that the costs could be reduced as well, depending on how efficient the additional buses can be planned. The process of choosing the best bid in the public procurement process will be more complicated when the contracts are less detailed compared to current situations.

14/03663 Targeting utility customers to improve energy savings from conservation and efficiency programs

Taylor, N. W. *et al. Applied Energy*, 2014, 115, 25–36.

Electric utilities, government agencies, and private interests in the USA have committed and continue to invest substantial resources – including billions of dollars of financial capital – in the pursuit of energy efficiency and conservation through demand-side management (DSM) programmes. While most of these programmes are deemed to be cost-effective, and therefore in the public interest, opportunities exist to improve cost-effectiveness by targeting programmes to those customers with the greatest potential for energy savings. This paper details an analysis of three DSM programmes offered by three Florida municipal electric utilities to explore such opportunities. First, the programmes' energy savings impacts were estimated; second, energy savings were measured and compared across subgroups of programme participants as determined by their pre-intervention energy performance, and third, potential changes in programme impacts that might be realized by targeting specific customers for participation in the DSM programmes were explored. All three programmes resulted in statistically significant average (per-participant) energy savings, yet average savings varied widely, with the customers who performed best (i.e. most efficient) before the intervention saving the least energy and those who performed worst (i.e. least efficient) before the intervention saving the most. Assessment of alternative programme participation scenarios with varying levels of customer targeting suggests that programme impacts could be increased by as much as 80% for a professional energy audit programme, just over 100% for a high-efficiency heat pump upgrade programme, and nearly 250% for an attic insulation upgrade programme. These findings are directly relevant for utility programme administrators seeking to improve programme outcomes.

14/03664 Thermal comfort and building energy consumption implications – a review

Yang, L. *et al. Applied Energy*, 2014, 115, 164–173.

Buildings account for about 40% of the global energy consumption and contribute over 30% of the CO_2 emissions. A large proportion of this energy is used for thermal comfort in buildings. This paper reviews thermal comfort research work and discusses the implications for building energy efficiency. Predicted mean vote works well in air-conditioned spaces but not naturally ventilated buildings, whereas adaptive models tend to have a broader comfort temperature ranges. Higher indoor temperatures in summertime conditions would lead to less prevalence of cooling systems as well as less cooling requirements. Raising summer set point temperature has good energy saving potential, in that it can be applied to both new and existing buildings. Further research and development work conducive to a better understanding of thermal comfort and energy conservation in buildings have been identified and discussed. These include (i) social-economic and cultural studies in general and post-occupancy evaluation of the built environment and the corresponding energy use in particular, and (ii) consideration of future climate scenarios in the analysis of co- and tri-generation schemes for heating, ventilation and air-conditioning applications, fuel mix and the associated energy planning/distribution systems in response to the expected changes in heating and cooling requirements due to climate change.

14/03665 Transport energy consumption and saving in China

Wang, Y. F. *et al. Renewable and Sustainable Energy Reviews*, 2014, 29, 641–655.

At present, energy consumption of transportation sectors is about one-third of the world's total energy consumption, such a proportion in China accounts for about 20%. Over the past decades, with the continuous development of the country's economy, China's energy consumption has increased rapidly. China became the world's largest energy consumer in 2009. Meanwhile, China's transportation energy consumption grows greatly, and the proportion of the transport terminal energy consumption is expanding considerably. Recently, a number of theoretical methods and technical schemes focusing on China's transport energy consumption and saving were reported. This paper, by reviewing the existing reports, discusses and analyses the current status of China's transportation energy consumption including four different transport sectors: road, railway, waterway and civil aviation, and outline the trend of China's transport energy consump-

tion and the four sectors. In addition, the technological status of China's energy savings in road, railway and waterway transportation as well as civil aviation and their development direction are also presented. By analysing the major development barriers of the technology and policy of China's transport energy savings, some related policy suggestions are proposed.

17 ENERGY CONVERSION AND RECYCLING

14/03666 Characterization of biomass and high carbon content coal ash for productive reuse applications

Yeboah, N. N. N. *et al. Fuel*, 2014, 116, 438–447.

Productively reusing the waste residuals from energy production is an essential component in sustainable disposal and management of energy-related waste. In the USA, the world's second largest producer of coal next to China, over 118 million tons of coal combustion by-products are produced each year; only 44% of which are productively reused. In recent decades, advances in lowering CO_2, SO_x and NO_x emissions from coal combustion have changed the characteristics of the solid coal combustion products. In particular, the residual carbon content of fly ash generated at many US coal-fired power plants has increased, and has become more heterogeneous. Additionally, utilities are exploring the use of pure biomass as a fuel source, which results in a fly ash that is generated from a purely organic source. While much research effort has been devoted to understanding the properties and potential productive reuse alternatives for coal combustion products, relatively little research has been done on the by-products from biomass combustion or co-combustion. In this study, high carbon content coal ash, co-fired coal/biomass ash, and pure biomass ash from several US power plants were investigated. The ashes were characterized using a number of physical and chemical analysis techniques, including: scanning electron microscopy, laser diffraction, organic carbon content, nitrogen adsorption surface area, proximate and ultimate, X-ray fluorescence and X-ray diffraction analysis. Results showed little physical, chemical and mineralogical differentiation between coal ash and coal co-fired with biomass ash. However, the pure biomass ashes investigated in this study, showed significantly lower specific gravity, and primary oxide content, as well as coarser particle size distribution, higher residual carbon, higher heating value, and much higher specific surface area, when compared to the coal and co-fired ashes. These results have important implications on the potential for productive reuse of these waste materials.

14/03667 Efficient conversion of brown grease produced by municipal wastewater treatment plant into biofuel using aluminium chloride hexahydrate under very mild conditions

Pastore, C. *et al. Bioresource Technology*, 2014, 155, 91–97.

Wastes produced by oil/water separation at the wastewater treatment plant of Bari West in southern Italy were taken, characterized and converted. About 12% of this material was composed of greases, mainly made of free fatty acids (50%) and soaps (34%), and was easily separable by the aqueous phase through a hot centrifugation. After chemical activation of this fatty fraction, a direct esterification was carried out under very mild conditions (320 K and atmospheric pressure), converting more than 90% of the original free fatty acids into the respective methyl esters in less than 4 h, by using $AlCl_3{\cdot}6H_2O$. The activation energy correlated to the use of this catalyst was also calculated ($Ea_{est} = 43.9\,kJ\,mol^{-1}$). The very low cost of the biodiesel produced ($0.45\,€\,L^{-1}$) and the associated relevant specific energy ($5.02\,MJ\,kg^{-1}_{FAMEs}$) make such a process a really sustainable and effective example of valorization of a waste.

14/03668 Experimental and analytical study of the internal recycle-effect on the heat transfer for the power-law fluid in a double-pass flat-plate heat exchanger with constant wall temperature

Lin, G.-G. *et al. International Communications in Heat and Mass Transfer*, 2014, 50, 44–51.

A conjugated Graetz problem of the double-pass flat-plate heat exchanger with internal recycle at uniform wall temperature was solved analytically using the orthogonal expansion technique for the power-law fluid. The mathematical formulation was derived for a fully developed laminar flow through the flat-plate channels by ignoring axial conduction and assuming temperature-independent fluid properties. A constant wall temperature, and both the continuous temperature and the same heat flux at the interface of the two adjacent subchannels made by inserting an impermeable sheet in between, were considered as the thermal boundary conditions. Experiments were carried out in order to validate the proposed mathematical formulation and the results can be very satisfactory. It is found that the recycle ratio and the impermeable-sheet position play significant influences on the efficiencies of this double-pass flat-plate heat exchanger. But, if the power consumption is also evaluated, the performance declines for the double-pass heat exchanger with large reflux ratios. The heat-transfer efficiency enhancement for the power-law fluid with a smaller power-law index is found to be less than that with a larger one, however, if both the heat transfer efficiency and the power consumption increment are considered together, the fluid with a smaller index would have a higher performance.

14/03669 Heat recovery from export gas compression: analyzing power cycles with detailed heat exchanger models

Rohde, D. *et al. Applied Thermal Engineering*, 2013, 60, (1–2), 1–6.

Offshore oil and gas production platforms release substantial amounts of heat to the sea. A major source of waste heat is the cooling unit for the compressed export gas. In this paper, the potential for power production from this heat source is analysed. The emphasis was not only put on net power output, but also on system size, which is a key parameter for offshore operation. To find a suitable trade-off between those two values, a cycle calculation tool was programmed which uses detailed heat exchanger models to ensure a fair comparison of the different working fluids. A subcritical propane cycle, a transcritical CO_2 cycle and a transcritical cycle with a mixture of propane and ethane were analysed. It was shown that more than 10% of the export gas compression work could be recovered. The hydrocarbon mixture shows very promising results, but a more comprehensive study is required to reach an economical decision between power output and system size.

14/03670 Liquid fuel production from waste tyre pyrolysis and its utilisation in a Diesel engine

Frigo, S. *et al. Fuel*, 2014, 116, 399–408.

The possibility of using a liquid fuel in diesel engines derived from waste synthetic polymeric matrices, such as scrap tyres, was evaluated in this paper. The liquid fuel was obtained by a combined thermo-mechanical cracking process carried out at moderate temperatures (300–500 °C). Fuel properties of the pyrolytic oil were analysed with standard methods, showing density, viscosity, calorific value and flash point comparable to those of a commercial automotive diesel fuel (DF), but with significantly higher sulfur content and a lower cetane number. Also the other pyrolysis products (gas and solid) were analysed in terms of yield and composition in order to individuate their potential re-uses. A preliminary engine investigation was carried out on a 440 cm^3 single-cylinder diesel engine using two tyre pyrolysis oil (TPO)–diesel blends: TPO20 (containing 20% TPO and 80% of DF in volume basis) and TPO40. The cytotoxicity and genotoxiticy of the particulate from engine exhaust emissions were evaluated on D7 strain of *Saccharomyces cerevisiae* yeast cells by *in vitro* short-term tests. Results were compared with those obtained using the DF only. Engine performance, evaluated at different engine speed and loads, showed that the use of TPO20 not involve significative differences in terms of torque, power, specific fuel consumption and exhaust emissions in respect to those obtained using the DF, while the use of TPO40 leads to a general worsening in engine combustion characteristics. Lubricant oil analysis, made at the end of the tests, showed a certain level of contamination. No meaningful mechanical inconvenience occurred during the engine experimental activity. In vitro assays on particulates showed similar cytotoxic potency and no genotoxic effect for diesel and TPO/diesel blend emissions.

14/03671 Performance analysis on a new multi-effect distillation combined with an open absorption heat transformer driven by waste heat

Zhang, X. *et al. Applied Thermal Engineering*, 2014, 62, (1), 239–244.

In this paper, a new water distillation system, which consists of either a single- or multi-effect distiller combined with an open absorption heat transformer (OAHT), has been proposed. The new integrated system can be used for distilling waste water with high amounts of SiO_2 from heavy oil production, and the resultant distilled water can be supplied to steam boilers to produce high quality steam which in turn is injected into oil reservoirs to assist with heavy oil recovery. The thermodynamic cycle performances for these new integrated distillation systems were simulated based on the thermodynamic properties of the aqueous solution of LiBr as well as the mass and energy balance of the system. The results indicate that combined with OAHT, the waste heat at 70 °C can be elevated to 125 °C and thereby produce steam at 120 °C in the absorber, which is able to drive a four-effect distiller to produce distilled water. For a single-effect and four-effect distiller, the co-efficients of performance are approximately 1.02 while the performance ratios are 2.19 and 5.72, respectively. Therefore, the four-effect distillation system combined with an OAHT is more thermally effective and is an ideal option to process the waste water in oilfields.

14/03672 Performance prediction and optimization of a waste-to-energy cogeneration plant with combined wet and dry cooling system

Barigozzi, G. *et al. Applied Energy*, 2014, 115, 65–74.

The present study is focused on a waste-to-energy plant located in northern Italy that produces electric power and thermal energy from the non-recyclable fraction of municipal and industrial solid waste (800,000 tons/year). In cold months, heat is provided to a district heating system. Another peculiarity of this plant is that the condenser system is organized with an air condenser and a water-cooled condenser, coupled with a wet cooling tower. This work shows how the net power output can be maximized by properly regulating the combined wet and dry units of the combined cooling system. A detailed model of the steam cycle was performed by means of a commercial code (Thermoflex). Off-design performance was carefully predicted to simulate accurately the real thermal cycle behaviour. Once the power cycle performance has been predicted over an extensive range of operating conditions, an optimal search method was implemented to find the set of variables allowing the wet and dry cooling system to be regulated so that the maximum net power is achieved. In general, the best strategy resulted in loading as much as possible the wet cooling system to reduce the operational cost of the dry air condenser. Conversely, the whole exhaust steam flow rate has to be sent only to the air condenser when the district heating water request is very large, i.e. in coldest months.

14/03673 Pilot-scale investigation on slurrying, combustion, and slagging characteristics of coal slurry fuel prepared using industrial wasteliquid

Liu, J. *et al. Applied Energy*, 2014, 115, 309–319.

The large amount of industrial waste liquid generated during various industrial processes has raised serious environmental issues. A coal–waste liquid slurry (CWLS) is proposed to dispose such waste liquids, which are used as a substitute for clean water in the preparation of a coal-based slurry fuel. By using this method, a significant amount of clean water is conserved, and the environmental problems caused by waste liquid discharge are resolved. However, the high content of organic matters, alkaline metal ions, and sulfur and nitro compounds considerably affects the slurrying, combustion, slagging and pollution emission characteristics of CWLS. In this study, these characteristics are experimentally studied using a pilot-scale furnace. The results reveal that, compared with conventional coal–water slurry (CWS), CWLS exhibits a good performance with respect to slurrying, combustion, and pollution emission, i.e. low viscosity, rapid ignition, high flame temperature, high combustion efficiency and low pollution emission. CWLS has a relatively low viscosity of 278 and 221 mPa s and exhibits shear-thinning pseudoplastic behaviour without the use of any additive agent. In contrast, CWS requires the use of an additive agent to achieve good fluidity, and its viscosity is 309 mPa s. The maximum flame temperature of the two CWLSs (CWLS-A and CWLS-B) is 1309.0 and 1303.1 °C, respectively, and their respective combustion efficiency is 99.61% and 99.42%. The values of both these parameters are greater than those obtained in the case of CWS. However, the alkaline metal ions in the waste liquid lead to a considerable slagging status. This status improves significantly after turning down the operating load.

14/03674 Pyrolysis treatment of poultry processing industry waste for energy potential recovery as quality derived fuels

Marculescu, C. and Stan, C. *Fuel*, 2014, 116, 588–594.

The paper presents the thermal–chemical treatment of residues from poultry slaughterhouses using the pyrolysis process for derived-fuel production with high-energy density properties, as alternative solution for waste-to-energy conversion. The residue consists of chicken feathers with traces of blood and offal, sampled directly from the industrial processing line. A specially designed tubular batch reactor was used for the externally heated atmospheric pressure pyrolysis. Experimental campaign reliability was ensured by using raw waste products and industrial operating parameters with temperatures in the range of 350–800 °C. The experiments were developed with respect to sample mass reduction rate, thermal degradation process kinetics, reaction products distribution, physical–chemical properties and specific energy content. The influence of process parameters on char, tar and gas formation was quantified along with the mechanisms involved. The experiments revealed that minimum treatment periods for complete volatile fraction release vary between 35 and 3 min depending on process temperature. The char mass fraction represents 40% to 10% of the pyrolysis products. The minimum tar fraction is generated at 350 °C and increases continuously to the maximum reached at 600 °C. The pyrolysis gas yield is quasi-constant between 350 and 450 °C and decreases with temperature rising. The energy content of pyrolysis products was determined based on their low heating value and mass fractions. The study aimed at minimum energy consumption and quality derived fuels production using the pyrolysis process as pretreatment stage applied to a potential renewable fuel with high specific energy density (26 MJ/kg) but low combustible properties due to high water content (up to 70%).

14/03675 Semi-pilot scale production of hydrogen from organic fraction of solid municipal waste and electricity generation from process effluents

Sekoai, P. T. and Kana, E. B. G. *Biomass and Bioenergy*, 2014, 60, 156–163.

The production of hydrogen from the organic fraction of solid municipal waste (OFSMW) was studied on a semi-pilot scale. The potential of generating electricity using the process effluents was further assessed using a two-chambered microbial fuel cell. A maximum hydrogen fraction of 46.7% and hydrogen yield of 246.93 ml $H_2\,g^{-1}$ total volatile solids was obtained at optimum operational setpoints of 7.9, 30.29 °C and 60 h for pH, temperature and hydraulic retention time, respectively. A maximum electrical power density of 0.21 $W\,m^{-2}$ (0.74 $A\,m^{-2}$) was recorded at 500 Ω and the chemical oxygen demand removal efficiency of 50.1% was achieved from the process. The process economics of energy generation from organic wastes could be significantly improved by integrating a two-stage process of fermentative hydrogen production and electricity generation.

14/03676 Simultaneous optimization of heat-integrated water networks involving process-to-process streams for heat integration

Ahmetović, E. and Kravanja, Z. *Applied Thermal Engineering*, 2014, 62, (1), 302–317.

This paper presents an extension of the authors' recent work, in which they addressed the simultaneous synthesis of heat-integrated water networks. The novelty and goal of this work is the development of an extended superstructure and simultaneous optimization model of heat-integrated water networks now involving process-to-process streams, and other streams within the overall network, for heat integration. Those heat-integration opportunities have not yet been fully taken into account in most existing models of heat-integrated water networks. In this study, the authors presented two strategies for heat integration of process-to-process streams. The first one includes the placement of heat exchangers on each hot and cold process-to-process stream. The second allows for the cooling and splitting of hot streams, and heating and splitting of cold streams. This extended model was formulated as a non-convex mixed-integer non-linear programming problem. The objective was to minimize the total annual network cost. Two examples with single and multiple contaminants are used in order to demonstrate that involving process-to-process streams for heat integration, novel and improved solutions can be obtained compared to those reported in the literature.

14/03677 Waste heat usage

Swithenbank, J. *et al. Applied Thermal Engineering*, 2013, 60, (1–2), 430–440.

This paper presents an overview of heat transfer issues arising from the current national situation regarding energy sustainability and global warming. An important concern addressed is the inefficiency of present fuel usage in the UK – namely large-scale, fossil-fuelled power stations and energy-from-waste plants that discharge huge quantities of low-grade heat to the atmosphere. Other countries recover this thermal energy and use it to supply heating and hot water to nearby domestic, commercial and industrial buildings. Such district heating schemes can provide cost-effective and low-carbon energy to local populations. Although the amount of district heating in the UK is small, Sheffield currently has an award-winning city-wide district energy network that incorporates a combined-heat-and-power energy-from-waste facility, providing electricity and district heating; this scheme is explored in this paper, with the purpose of identifying potential expansions through heat mapping. Heat transfer will clearly need to play a major part in one or more of the various power generation technologies proposed to meet the demands of the developing energy situation – these comprise high-efficiency systems using high-temperature regenerators or high-pressure combustion and energy storage utilizing supercritical steam accumulators, which are all considered in this paper.