01 SOLID FUELS

Sources, winning, properties

12/00555 Coal facies in a Cenozoic paralic lignite bed, Krabi Basin, southern Thailand: changing peat-forming conditions related to relative sea-level controlled watertable variations

Petersen, H. I. and Ratanasthien, B. *International Journal of Coal Geology*, 2011, 87, (1), 2–12.

The Cenozoic Krabi Basin in the southern part of peninsular Thailand contains about 112 million tons proven coal reserves. At present, coal is only produced from the Bang Mark mine located in the southern part of the basin, where the main lignite bed is 7–20 m thick. The lignite bed occurs in an overall paralic succession. The present paper investigates the depositional conditions of an approximately 8 m thick lignite bed (main seam) in the Bang Mark mine using organic petrography, including maceral ratios, and geochemistry. The results are further interpreted in a sequence stratigraphic context. The lignite is of low rank and is completely dominated by huminite indicating generally oxygen-deficient conditions in the precursor mire. Very low inertinite contents suggest rare occurrences of wildfires. The lower part of the lignite bed represents a topogenous fresh water peat mire with open water areas that in few cases may have experienced influx of saline water. The peat mire was subjected to periodic inundations and deposition of siliciclastics. Tissue preservation was relatively poor. The upper part of the lignite bed represents a slightly domed fresh water ombrogenous peat mire with a stable watertable and a balance between peat accumulation and accommodation space creation that favoured preservation of plant tissues. In general, the mire vegetation changed from less woody in the topogenous mire to more arborescent in the ombrogenous mire, where plants with suberinized wood cell walls also were more frequent. Decompacted, the lignite bed corresponds to a minimum of about a 11 m peat deposit that records approximately 22,000–55,000 years of peat accumulation. Watertable rise in the peat mire was controlled overall by relative sea-level rise. In a sequence stratigraphic context, the lignite bed overlies a terrestrialization surface (TeS; sensu Diessel, 2007) and the lowermost part records peat formation during a falling watertable and a decreasing accommodation/peat accumulation ratio (terrestrialization). An accommodation reversal surface (ARS; sensu Diessel, 2007) indicates a change to paludification style of peat formation characterized by rising watertable and a high accommodation/peat accumulation ratio. Another ARS marks a gradual change to a situation with a balanced accommodation/peat accumulation ratio. The overall watertable rise throughout peat formation, but at a gradually slower rate from base to top, suggests that the lignite bed could be located in the late transgressive systems tract (TST).

12/00556 Effect of the effective stress coefficient and sorption-induced strain on the evolution of coal permeability: experimental observations

Chen, Z. *et al. International Journal of Greenhouse Gas Control*, 2011, 5, (5), 1284–1293.

Permeability is one of the most important parameters for CO_2 injection in coal to enhance coalbed methane recovery. Laboratory characterization of coal permeability provides useful information for *in situ* permeability behaviour of coal seams when adsorbing gases such as CO_2 are injected. In this study, a series of experiments have been conducted for coal samples using both non-adsorbing and adsorbing gases at various confining stresses and pore pressures. The observations have showed that even under controlled stress conditions, coal permeability decreases with respect to pore pressure during the injection of adsorbing gases. In order to find out the causes of permeability decrease for adsorbing gases, a non-adsorbing gas (helium) is used to determine the effective stress coefficient. In these experiments using helium, the impact of gas sorption can be neglected and any permeability reduction is considered as due to the variation in the effective stress, which is controlled by the effective stress coefficient. The results show that the effective stress coefficient is pore pressure dependent and less than unity for the coal samples studied. The permeability reduction from helium experiments is then used to calibrate the subsequent flow-through experiments using adsorbing gases, CH_4 and CO_2. Through this calibration, the sole effect of sorption-induced strain on permeability change is obtained for these adsorbing gas flow-through experiments. In this paper, experimental results and analyses are reported including how the impact of effective stress coefficient is separated from that of the sorption-induced strain on the evolution of coal permeability.

12/00557 Evaluation of the reservoir permeability of anthracite coals by geophysical logging data

Li, J. *et al. International Journal of Coal Geology*, 2011, 87, (2), 121–127.

Permeability is one of the most significant reservoir parameters. It is commonly obtained by experiment, history simulation, injection/falloff well test and geophysical logging. Among these, geophysical logging remains as the most economic and efficient technique in evaluating coal permeability in the vicinity of an open-hole. In this paper, geophysical logging data are used to evaluate the coal reservoir permeability for the No. 3 coal seam in the southern Qinshui Basin (Fanzhuang and Zhengzhuang coal zones). Ideally coal reservoirs consist of coal matrix and fracture networks that can be represented by a model called 'a collection of sheets'. Based on the model, coal reservoir permeability can be quantitatively calculated using the theoretical formula of $kf = 8.50 \times 10^{-4} w^2 \phi_f$, in which fracture width (w) and fracture porosity (ϕ_f) were obtained by dual laterolog and density logging data, respectively. Calculative results show that coal reservoir permeability ranged from 0.017 to 0.617 mD for the Fanzhuang coal zone and from 0.047 to 1.337 mD for the Zhengzhuang coal zone. The permeability decreases with coal burial depth, reflecting variations in penetration capability of coal reservoirs at varying depths. Comparing results with those from injection/falloff well tests, however, shows that the model-calculated permeability is slightly higher. This is expected because the model did not include the influence from coal anisotropy.

12/00558 Influence of blending methods on the co-gasification reactivity of petroleum coke and lignite

Zhan, X. *et al. Energy Conversion and Management*, 2011, 52, (4), 1810–1814.

The purpose of this paper is to investigate the influence of blending methods on the co-gasification of petroleum coke and lignite with CO_2 using a thermogravimetric system at 0.1 MPa. The weight loss curves, XRD analysis, SEM images, BET specific surface area, were investigated. It was observed that petroleum coke shows a low reactivity because of the graphitic carbon structure, low catalyst content and small specific surface area. Blending with lignite can get a high reactivity. The co-gasification reactivity was significantly influenced by blending methods. Wet grinding is much effective than dry grinding. Long grinding time made lignite show greater BET specific area. And the sample in long grinding time has more association chances between petroleum coke and AAEM species. The co-gasification reactivity increases linearly with a rise of BET specific area.

12/00559 Influence of pressure on the release of inorganic species during high temperature gasification of coal

Bläsing, M. and Müller, M. *Fuel*, 2011, 90, (6), 2326–2333.

Alkali metal, sulfur, and chlorine species released during coal gasification are of concern, because they can lead to problems in colder parts of the plant. Therefore, hot gas cleaning technology is recently under development. This clean-up strategy requires a comprehensive knowledge of the release characteristics of inorganic compounds. The principal objective of this work was to provide details of the influence of pressure on the release of key chemical species, e.g. sodium, potassium, sulfur and chlorine. Hence, a total of 19 different coals were investigated in lab-scale gasification experiments in an electrical-heated pressurized furnace at absolute pressures of 2, 4, and 6 bar in an atmosphere of He/7.5v%O_2 at 1325 °C. Hot gas analysis was carried out by molecular beam mass spectrometry. The quantitative results showed a decreasing release of $^{34}H_2S^+$, $^{36}HCl^+$, $^{39}K^+/^{39}NaO^+$, $^{58}NaCl^+$, $^{64}SO_2^+$, and $^{74}KCl^+$ with increasing pressure. The discussion was supported by thermodynamic calculations.

12/00560 Mechanistic investigation of chemical looping combustion of coal with Fe_2O_3 oxygen carrier

Wang, B. *et al. Fuel*, 2011, 90, (7), 2359–2366.

The reaction of three Chinese coals with Fe_2O_3 oxygen carrier (OC) was performed in a thermogravimetric analyser (TGA), with special focuses on the effects of varying heating rate and coal rank on reactivity. Fourier transform infrared spectroscopy (FTIR) was used to *in situ* detect the emitted gases from TGA. Field scanning electron microscopy/energy-dispersive X-ray spectrometry (FSEM–EDX) was used to study the morphology and elemental compositions of the reaction residues collected from TGA and the related phase evaluation was further identified by X-ray diffraction (XRD). Through all these experiments, it was found that the pyrolysis of coal samples without Fe_2O_3 OC under N_2 atmosphere underwent the dehydration and the ensuing primary and secondary pyrolysis stages. The increasing heating rate shifted the characteristic temperature (T_m) of the primary pyrolysis to a higher temperature and favoured a more rapid generation of volatile matters. When the three coals reacting with Fe_2O_3 OC, TGA results demonstrated even over 200 °C, the reaction still experienced the partial pyrolysis at the relatively low temperature and the ensuing two

reactions of Fe_2O_3 with the pyrolysis products at the primary and secondary stages. The coal of low rank with high volatile content should be preferred for the full conversion of coal into CO_2. Furthermore, the activation energy of Fe_2O_3 OC reacting with PDS at its primary pyrolysis stage was the largest, more than 70 kJ/mol. Finally, SEM–EDX and further XRD analysis of the residues from the reaction of PDS with Fe_2O_3 OC indicated the reduced counterpart of Fe_2O_3 was Fe_3O_4, and some inert iron compounds such as Fe_2SiO_4 and $FeAl_2O_4$ were also generated, which might deteriorate the reactivity of Fe_2O_3 OC.

12/00561 Petrographic, geochemical, and mycological aspects of Miocene coals from the Nováky and Handlová mining districts, Slovakia

O'Keefe, J. M. K. *et al. International Journal of Coal Geology*, 2011, 87, (3–4), 268–281.

Fungi have once again become a topic of interest to coal scientists in their roles as agents of maceral formation. Recent works have demonstrated that fungi occur in association with woody remains, resins, and cuticles in coalified materials of a variety of ages, in addition to coal-balls and compression–impression fossils, where they are already well known. These forms, however, have only been viewed as cross-sections along a polished plane. Assigning the fungi to family, much less determining which fungi they represent is very difficult in this orientation. Fungal identifications are necessary to the continuance of this research into the origin of coal macerals because of the need to know if macrinite begins to form prior to incorporation into the peat, which could be demonstrated by its association with symbiotic and parasitic, rather than saprophytic fungi. This study examines the fungal remains recovered from eight coal samples from Miocene-age coals in the Nováky and Handlová mining districts of Slovakia with the aim of making this distinction. These samples were collected in Slovakia as part of the US Geological Survey's World Coal Quality Inventory program and provided to the authors. The samples were processed using the O'Keefe technique for subbituminous coals and mounted for observation in transmitted light. Forms were identified using published works and consultation with a modern mycologist. Forms recovered through palynologic processing were compared to and correlated with forms seen in cross-section under reflected light.

Preparation

12/00562 Microstructural evolution of high temperature treated anthracites of different rank

Rodrigues, S. *et al. International Journal of Coal Geology*, 2011, 87, (3–4), 204–211.

The present work is focused on the microstructural evolution of major components of carbonaceous samples during high temperature treatment, i.e. vitrinite in raw anthracites and dense particles in the heated samples. Three anthracites from distinct geological settings, with an *Rr* of 2.62%, 5.23%, and 6.25% (PBEB, ACB, and DB, respectively) were chosen for this research. The raw samples were previously carbonized at 1000 °C, and then subjected to high temperature treatment (HTT) at 1500, 2000, and 2500 °C, in a graphite furnace. From the results obtained by optical microscopy (RIS parameters), micro-Raman spectroscopy, and X-ray diffraction, it was possible to evaluate the subsequent structural and microtextural evolution of the heat treated materials. It was found that, during the carbonization process up to 1500 °C, the transformations are essentially of a chemical nature and are expressed by chemical and optical parameters (RIS main axes and R_{ev} parameter). The magnitude of these changes is higher for the lower rank heat treated anthracite (PBEBC series). The structural order parameters obtained by X-ray diffraction show an increase in disorder at 1000 °C and a slight improvement after heat treatment at 1500 °C. The G band FWHM (cm^{-1}) exhibits the same tendency at 1000 °C. However, due to the small size of the crystallites, this Raman parameter continues to increase at 1500 °C. After 2000 °C, there is an increase in the structural order in the materials of the heat treated samples. A three-dimensional ordering was observed in the materials of the DBC carbonized anthracite at 2500 °C, as exhibited by the X-ray diffraction parameters and Raman spectral features. The PBEBC and ACBC carbonized anthracites still retain their turbostratic structure after heat treatment at 2500 °C.

12/00563 The effect of coal sulfur on the behavior of alkali metals during co-firing biomass and coal

Yang, T. *et al. Fuel*, 2011, 90, (7), 2454–2460.

Biomass contains high amounts of volatile alkali metals and chlorine, which can cause deposition, corrosion and agglomeration during combustion. Meanwhile coal contains a certain amount of sulfur that produces serious environmental pollution following combustion. To investigate the effects of sulfur on the migration of alkali metals during biomass and coal co-combustion, thermodynamic equilibrium calculations were applied and experiments were performed in a laboratory scale reactor combining with a scanning electron microscope (SEM), X-ray powder diffraction (XRD) and other analytical approaches. The results indicate that inorganic sulfur FeS_2 addition significantly enhanced the formation of potassium sulfate when the S/K molar ratio was less than 2. Meanwhile increasing FeS_2 dosage reduced the formation of KCl(g) and KOH(g) and increased the release of HCl(g). In addition potassium sulfate can react with silica and aluminium to form potassium aluminosilicates and release HCl at the S/K molar ratio above 4.

Transport, storage

12/00564 Electromagnetic emission graded warning model and its applications against coal rock dynamic collapses

Wang, E. *et al. International Journal of Rock Mechanics and Mining Sciences*, 2011, 48, (4), 556–564.

Dynamic collapses of deeply mined coal rocks are severe threats to miners. In order to predict the collapses more accurately using electromagnetic emission (EME), the authors established a loaded coal rock EME electromechanical coupling model based on statistical damage mechanics. By using it, they numerically simulated both the accumulative pulse and strain ratios. They further improved the model with the Weibull pattern parameter, which has important effects on simulated results and can be applied to judge coal's homogeneity, and determined the pattern parameter and its value domain. Based on the revised model and the characteristics of coal rock deformation and fracture, the authors set up an EME-graded warning criteria against coal rock dynamic collapses by determining static critical coefficient and dynamic trend coefficient. They have applied this model to predict and deal with coal and gas outburst and rock burst occurring at Xie I and Taoshan mines, respectively. All these verifications show that the model has many advantages and provides more sensitive and accurate warning for dynamic collapses.

12/00565 Mechanical properties of abandoned and closed roadways in the Kushiro Coal Mine, Japan

Fujii, Y. *et al. International Journal of Rock Mechanics and Mining Sciences*, 2011, 48, (4), 585–596.

The objective of this research is to clarify the mechanical properties and self-healing ability of the excavation damaged zone (EDZ) around rock caverns in clastic-rock. Observations of nearly 100 closed roadways up to 50 years old, which can be regarded as very severe EDZs with no initial sealability and are up to 300 m deep in clastic-rock, were made at the Kushiro coal mine, Japan, to accomplish the objective. Most old roadways were closed, though a few remain open. Closure of old roadways was mainly due to roof deflection and/or floor heave. Large plastic deformations dominated; however, severe fractures were seldom observed in closed old roadways. Rayleigh wave velocity and hydraulic conductivity in the closed old roadways were in the range of 0.3–1.2 km/s and 5×10^{-7}–1×10^{-7} m/s, respectively, and those in EDZ and EdZ (excavation disturbed zone) around recently excavated roadways were 1.1–1.8 km/s and 1×10^{-8}–5×10^{-8} m/s, respectively. The extent of EDZ around the present tailgate was in the range of 1–5 m. Mechanical excavation and prevention from water are suggested as the key points for long-term maintenance of rock repositories. Pressurization from inside the cavern to decrease the permeability of EDZ is proposed for maintenance of rock repositories in medium-hard clastic-rock masses at similar depths for long periods.

Economics, business, marketing, policy

12/00566 Comprehensive evaluation of coal-fired power plants based on grey relational analysis and analytic hierarchy process

Xu, G. *et al. Energy Policy*, 2011, 39, (5), 2343–2351.

In China, coal-fired power plants are the main supplier of electricity, as well as the largest consumer of coal and water resources and the biggest emitter of SO_x, NO_x, and greenhouse gases (GHGs). Therefore, it is important to establish a scientific, reasonable, and feasible comprehensive evaluation system for coal-fired power plants to guide them in achieving multi-optimization of their thermal, environmental, and economic performance. This paper proposes a novel comprehensive evaluation method, which is based on a combination of the grey relational analysis (GRA) and the analytic hierarchy process (AHP), to

assess the multi-objective performance of power plants. Unlike the traditional evaluation method that uses coal consumption as a basic indicator, the proposed evaluation method also takes water consumption and pollutant emissions as indicators. On the basis of the proposed evaluation method, a case study on typical 600 MW coal-fired power plants is carried out to determine the relevancy rules among factors including the coal consumption, water consumption, pollutant, and GHG emissions of power plants. This research offers new ideas and methods for the comprehensive performance evaluation of complex energy utilization systems, and is beneficial to the synthesized consideration of resources, economy, and environment factors in system optimizing and policy making.

12/00567 Evaluation of ground movement and damage to structures from Chinese coal mining using a new GIS coupling model
Djamaluddin, I. *et al. International Journal of Rock Mechanics and Mining Sciences*, 2011, 48, (3), 380–393.
In this paper, combining a theoretical method of predicting subsidence over time and using a geographical information system (GIS), a GIS-based dynamic model is proposed to simulate the phenomenon of progressive movement distribution from large sequential mining. The theoretical method uses stochastic medium concept involving Knothe time function for basic governing equations to calculate progressive movement because this solutions have been widely developed and used in Chinese mining practice to solve the coal extraction problem under building, railways, and rivers. In order to assess the impact of progressive movement to the surface structures, a fuzzy model is suggested to identify damage classifications with contributions of subsidence calculations and building mesh data. For implementation of the GIS-based prediction and assessment model, a new GIS coupling model is established by implementing tight coupling strategy using the component object model (COM) program to overcome the problems of complex model integration for dynamic prediction and assessment. Furthermore, this paper demonstrates the effectiveness of this GIS-based model for prediction and evaluation of subsidence-induced damage from coal mining beneath surface structures in China.

Derived solid fuels

12/00568 Coke formation and performance of an intermediate-temperature solid oxide fuel cell operating on dimethyl ether fuel
Su, C. *et al. Journal of Power Sources*, 2011, 196, (4), 1967–1974.
Dimethyl ether (DME) as a fuel of SOFCs is investigated with great attention paid to coke formation over the Ni-YSZ anode. DME is easily decomposed to CH_4, CO and H_2 at temperatures above 700 °C, with total conversion occurring at 850 °C over the Ni-YSZ catalyst. These data suggest that the DME electro-oxidation likely proceeds via an indirect pathway. O_2-TPO analysis, laser Raman spectroscopy and SEM–EDX characterizations demonstrate coke formation over Ni-YSZ, which is obvious and become more prevalent at higher temperatures. The introduction of CO_2 in the fuel gas decreases the CH_4 selectivity and effectively suppresses coke formation above 700 °C. The suppression effect is increasingly apparent at higher temperatures. At 850 °C, the anode still maintains geometric integrity after exposure to DME–CO_2 (1:1, volume ratio) under OCV condition. With DME or DME–CO_2, the fuel cell power output is comparable to results obtained by operating with 3% water humidified hydrogen. No obvious cell degradation from the anode is observed when operating with DME–CO_2, while it is obvious with DME. The introduction of CO_2 may be a good choice to suppress the coke formation when operating on DME; however, the proper selection of operation temperature is of significant importance.

12/00569 The combustion reactivity of coal chars in oxyfuel atmosphere: comparison of different random pore models
Fei, H. *et al. Journal of Analytical and Applied Pyrolysis*, 2011, 91, (1), 251–256.
Recently the oxyfuel combustion of coal chars having a significant impact on reducing greenhouse emissions is gradually paid extensive attention by many researchers, but only a limited number of studies have focused on its reaction mechanism. Therefore, it is important to investigate the combustion mechanism of coal chars in oxyfuel atmosphere, while random pore model (RPM) is usually recommended as a model for the comprehensive simulation of coal chars reaction. In this context, the values of structure parameter ψ in RPM were calculated based on pore structural character at various carbon conversions, and show interesting evolution phenomena keeping constant at the preceding reaction stage before increasing remarkably at the end of stage. Consequently, a new model, two-stage random pore model (TRPM), was applied to the coal chars combustion in oxyfuel atmosphere. Compared to other models such as RPM, the Struis model (model I), the Liu model (model II), and fractal random pore model (FRPM), it shows that two-stage random pore model was more accurate to describe coal chars combustion under oxyfuel conditions, especially at higher carbon conversions. In addition, the oxyfuel combustion process of coal chars at 1323 and 1373 K were analysed.

12/00570 The random pore model with intraparticle diffusion for the description of combustion of char particles derived from mineral- and inertinite rich coal
Everson, R. C. *et al. Fuel*, 2011, 90, (7), 2347–2352.
An investigation was undertaken to determine the applicability of the random pore model with intraparticle diffusion for the determination of the reaction kinetics for the combustion of chars particles derived from coals rich in minerals and inertinites. The char particles which were pyrolysed at 900 °C consisted of a dense carbon-containing fraction originating from the inert macerals (mainly inertinites), a high concentration of minerals and carbominerites, pores generated by the devolatilization of the reactive macerals and cracks as a result of the presence of minerals. Combustion experimentation was carried out with a thermogravimetric analyser using 1 mm particles with 20% (mole) oxygen in nitrogen at 287.5 kPa and low temperatures (450–600 °C) and with high gas flow rates. The random pore model with intraparticle diffusion (pores and cracks) was solved numerically according to a method consisting of a step-wise regression procedure. This was achieved by using carbon conversion and reduced time relationships to calculate the structural parameter and the initial Thiele modulus followed by determination of an initial lumped reaction rate and validation with conversion versus real time results. The model is characterized by a decreasing Thiele modulus (increasing porosity) occurring during the reaction period which gives rise to a transition to a chemically controlled reaction system. It was found that the initial overall reaction rate was controlled by intraparticle diffusion with an increasing influence with increasing temperature.

02 LIQUID FUELS

Sources, properties, recovery

12/00571 Geochemical evidence for coal-derived hydrocarbons and their charge history in the Dabei Gas Field, Kuqa Thrust Belt, Tarim Basin, NW China
Zhang, S. *et al. Marine and Petroleum Geology*, 2011, 28, (7), 1364–1375.
Large- to middle-scale thrust structures are important reservoir plays for coal-derived hydrocarbons in the foreland basins of north-west China, with both gas and some accompanying oil. In the Dabei gas field of the Kuqa Thrust, however, the oil and gas pools are vertically distributed in a quite unique way: (1) liquid oil and some dissolved gas are present in the Dawanqi Anticline with the reservoir at 300–700 m depth, forming the only oil field in the Kuqa Thrust; (2) gas and minor accompanying oil are found in the deep reservoir of the Dabei-1 and Dabei-2 thrust traps around 5000–6000 m depth; (3) an extremely dry gas pool is found in the Dabei-3 thrust trap where the depth of the reservoir is over 7000 m. Geochemical data suggest that the hydrocarbons in the Dawanqi Anticline and the Dabei thrust traps originated from a similar source, i.e. the underlying Jurassic coal measures, with some contribution from Jurassic lacustrine shales. The Jurassic source rocks did not start to generate oil until the Miocene (around the Kangcun Stage), and extended into the Pliocene (the Kuche Stage) with the main gas generation period in the Pliocene (the Kuche Stage) and the Quaternary. Because the traps formed relatively early, the Dabei-1 and Dabei-2 thrusts could trap some of the early generated oils, but most of the early charged oil was redistributed to the shallower Dawanqi Anticline during the Kuche Stage. The Dabei-3 thrust trap formed concurrently with major gas generation and thus could not trap liquid hydrocarbons. The difference in the vertical distribution of the hydrocarbon accumulations in the Dabei gas field resulted from a complex interplay of source variability, structural evolution of the basin and thermal maturation.

12/00572 Oil–oil and oil-source rock correlations in the Alpine Foreland Basin of Austria: insights from biomarker and stable carbon isotope studies
Gratzer, R. *et al. Marine and Petroleum Geology*, 2011, 28, (6), 1171–1186.

The Alpine Foreland Basin is a minor oil and moderate gas province in central Europe. In the Austrian part of the Alpine Foreland Basin, oil and minor thermal gas are thought to be predominantly sourced from Lower Oligocene horizons (Schöneck and Eggerding formations). The source rocks are immature where the oil fields are located and enter the oil window at about 4 km depth beneath the Alpine nappes indicating long-distance lateral migration. Most important reservoirs are Upper Cretaceous and Eocene basal sandstones. Stable carbon isotope and biomarker ratios of oils from different reservoirs indicate compositional trends in the west to east direction that reflect differences in source, depositional environment (facies), and maturity of potential source rocks. Thermal maturity parameters from oils of different fields are only in the western part consistent with northward displacement of immature oils by subsequently generated oils. In the eastern part of the basin different migration pathways must be assumed. The trend in $S/(S + R)$ isomerization of $\alpha\alpha\alpha$-C_{29} steranes versus the $\alpha\beta\beta$ (20*R*)/$\alpha\alpha\alpha$ (20*R*) C_{29} steranes ratio from oil samples can be explained by differences in thermal maturation without involving long-distance migration. The results argue for hydrocarbon migration through highly permeable carrier beds or open faults rather than relatively short migration distances from the source. The lateral distance of oil fields to the position of mature source rocks beneath the Alpine nappes in the south suggests minimum migration distances between less than 20 km and more than 50 km. Biomarker compositions of the oils suggest Oligocene shaly to marly successions (i.e. Schoeneck, Dynow, and Eggerding formations) as potential source rocks, taking into account their immature character. Best matches are obtained between the oils and units a/b (marly shale) and c (black shale) of the 'normal' Schöneck Formation, as well as with the so-called 'Oberhofen Facies'. Results from open system pyrolysis-gas chromatography of potential source rocks indicate slightly higher sulfur content of the resulting pyrolysate from unit b. The enhanced dibenzothiophene/phenanthrene ratios of oils from the western part of the basin would be consistent with a higher contribution of unit b to hydrocarbon expulsion in this area. Differences in the relative contribution of sedimentary units to oil generation are inherited from thickness variations of respective units in the overthrusted sediments. The observed trend towards lighter $\delta^{13}C$ values of hydrocarbon fractions from oil fields in a west to east direction are consistent with lower $\delta^{13}C$ values of organic matter in unit c.

12/00573 Permeability evolution in fractured coal: the roles of fracture geometry and water-content

Wang, S. *et al. International Journal of Coal Geology*, 2011, 87, (1), 13–25.

This study reports laboratory experiments that investigate the permeability evolution of an anthracite coal as a function of applied stress and pore pressure at room temperature as an analogue to other coal types. Experiments are conducted on 2.5 cm diameter, 2.5–5 cm long cylindrical samples at confining stresses of 6 to 12 MPa. Permeability and sorption characteristics are measured by pulse transient methods, together with axial and volumetric strains for both inert (helium) and strongly adsorbing (methane) gases and carbon dioxide gas. To explore the interaction of swelling and fracture geometry, the evolution of mechanical and transport characteristics for three separate geometries were measured – sample A containing multiple small embedded fractures, sample B containing a single longitudinal through-going fracture and sample C containing a single radial through-going fracture. Experiments are conducted at constant total stress and with varied pore pressure – increases in pore pressure represent concomitant (but not necessarily equivalent) decreases in effective stress. For the samples with embedded fractures (A and C) the permeability first decreases with an increase in pressure (due to swelling and fracture constraint) and then increases near-linearly (due to the overriding influence of effective stresses). Conversely, this turnaround in permeability from decreasing to increasing with increasing pore pressure is absent in the discretely fractured sample (B) – the influence of the constraint of the connecting fracture bridges in limiting fracture deformation is importantly absent as supported by theoretical considerations. Under water saturated conditions, the initial permeabilities to all gases are nearly two orders of magnitude lower than for dry coal and permeabilities increase with increasing pore pressure for all samples and at all gas pressures. It was also found that the sorption capacities and swelling strains are significantly reduced for water saturated samples – maybe identifying the lack of swelling as the primary reason for the lack of permeability decrease. Finally, the weakening effects were reported of gas sorption on the strength of coal samples by loading the cores to failure. Results surprisingly show that the strength of the intact coal (sample A) is smaller than that of the axially fractured coal (sample B) due to the extended duration of exposure to CH_4 and CO_2. Average post-failure particle size for the weakest intact sample (A) is found to be three times larger than that of the sample B, based on the sieve analyses from the samples after failure. The authors observe that fracture network geometry and saturation state exert important influences on the permeability evolution and strength of coal under *in situ* conditions.

12/00574 The structure of methane gas hydrate bearing sediments from the Krishna–Godavari Basin as seen from Micro-CT scanning

Rees, E. V. L. *et al. Marine and Petroleum Geology*, 2011, 28, (7), 1283–1293.

The Indian National Gas Hydrate Program (NGHP) Expedition 1, of 2006, cored through several methane gas hydrate deposits on the continental shelf around the coast of India. The pressure coring techniques utilized during the expedition (HYACINTH and PCS) enabled recovery of gas hydrate bearing, fine-grained, sediment cores to the surface. After initial characterization core sections were rapidly depressurized and submerged in liquid nitrogen, preserving the structure and form of the hydrate within the host sediment. Once on shore, high resolution X-ray CT scanning was employed to obtain detailed three-dimensional images of the internal structure of the gas hydrate. Using a resolution of 80 μm the detailed structure of the hydrate veins present in each core could be observed, and allowed for an in depth analysis of orientation, width and persistence of each vein. Hydrate saturation estimates could also be made and saturations of 20–30% were found to be the average across the core section with some portions showing highs of almost 60% saturation. The majority of hydrate veins in each core section were found to be orientated between 50° and 80° to the horizontal. Analysis of the strikes of the veins suggested a slight preferential orientation in individual sample sections, although correlation between individual sections was not possible due to the initial orientation of the sections being lost during the sampling stage. The preferred vein orientation within sample sections coupled with several geometric features identified in individual veins, suggest that hydraulic fracturing by upward advecting pore fluids is the main formation mechanism for the veined hydrate deposits in the K–G basin.

Transport, refining, quality, storage

12/00575 Anti-coking property of the SiO_2/S coating during light naphtha steam cracking in a pilot plant setup

Zhou, J. *et al. Journal of Analytical and Applied Pyrolysis*, 2011, 90, (1), 7–12.

On the basis of development in the laboratory, the SiO_2/S coating was prepared on the internal surface of HK40 alloy tube in a pilot plant setup. The coating sampled on the outlet of furnace tube was characterized by scanning electron microscope (SEM). The anti-coking property of the SiO_2/S coating was evaluated with light naphtha according to pressure changes. The morphologies and chemical components of cokes on the outlet of the coated and blank tubes were characterized by SEM and energy dispersive spectroscopy (EDS), respectively. The main product yields of light naphtha steam cracking were analysed by gas chromatography–mass spectrometry (GC–MS). The results show that the SiO_2/S coating is compact and has a thickness of 15 μm on the outlet of furnace tube. The SiO_2/S coating reduces coke yield by 60% compared to that observed in the blank tube during 8 h cracking run. However, the coke reductions of the SiO_2/S coating are both about 40% when the cracking time is 26 h and 66 h, respectively. The outlet of the coated tube has the exfoliated coke with a thickness of about 30 μm. The coke on the process side has many irregular particles, and the coke on the metal side is not filamentous coke but amorphous coke particles after the exfoliated coke is taken away. The yield of C_2H_4 has a slight increase in the coated tube, and the yield of C_4H_8 has a decrease. However, the SiO_2/S coating has little influence on the total yield of olefin.

12/00576 Combustion characteristics and emissions of Fischer–Tropsch diesel fuels in IC engines

Gill, S. S. *et al. Progress in Energy and Combustion Science*, 2011, 37, (4), 503–523.

This article gives a condensed overview of gas-to-liquid (GTL), biomass-to-liquid (BTL) and coal-to-liquid (CTL) theory and technology by the use of Fischer–Tropsch (F–T) processes. Variations of the F–T process can be used to tailor the fuel properties to meet end user needs as well as aid vehicle manufacturers in achieving forthcoming emission regulations. They do this by improving engine-out emissions and exhaust gas after-treatment performance. Regardless of feedstock or process, F–T diesel fuels typically have a number of very desirable properties, including a very high cetane number. This review focuses on how fuel properties impact pollutant emissions and draws together data from various studies that have been carried out over the past few years. Reduced emission levels as demonstrated in several publications have been attributed to several chemical and physical characteristics of the F–T diesel fuels including reduced density, ultra-low sulfur levels, low aromatic content and high cetane rating, but not all of them contribute to the same extent to the emissions reduction.

12/00577 Hydride tank storage system dimensioning on the base of their dynamic behavior
D'Orazio, A. *et al. International Journal of Hydrogen Energy*, 2011, 36, (13), 7902–7908.
The conditions in which the metal hydride adsorbs and release hydrogen are crucial aspects for integrating the fuel tank in a working system. In this paper the characterization of a metal hydride alloy tank has been analysed and reported. In particular the dynamic behaviour has been evaluated to propose a method to design a tank system. Indeed, to calculate the number of tanks, the evaluation of the energy requirement could be not enough because the available hydrogen depends not only on the quantity contained in the tank, but also on other dynamic factors which influence the kinetics and hydrogen flow such as the temperature and, therefore, the heat exchange system. By experimental data it has been individuated a procedure to build a curve, realizing a relationship between flow and maintaining time, in order to dimensioning a hydrogen system storage.

12/00578 Influence of the pressure holding time on strain generation in fuel injection lines
Basara, A. *et al. International Journal of Pressure Vessels and Piping*, 2011, 88, (4), 132–137.
An influence of the pressure holding time on residual strain generation during the autofrettage process was studied experimentally for the first time in the present work. It is the state of the art that fuel injection lines are held at the autofrettage pressure for only a few seconds in an industrial production. In doing so, it is assumed that a desirable residual stress–strain pattern is generated. However, the results of the experimental investigations outlined in this work indicated that completion of the plastic deformation caused by the autofrettage process and generation of the desirable stress–strain pattern require a much longer period. As shown, a third-order polynomial equation best described the interdependence between the time required for the completion of the process, the corresponding autofrettage pressure and the generated strain state. The method presented can be used as a tool for the determination of the optimal autofrettage process parameters in industrial production of fuel injection lines.

12/00579 Optimization of hydrogen production via coupling of the Fischer–Tropsch synthesis reaction and dehydrogenation of cyclohexane in GTL technology
Rahimpour, M. R. and Bahmanpour, A. M. *Applied Energy*, 2011, 88, (6), 2027–2036.
In this study, a thermally-coupled reactor containing the Fischer–Tropsch synthesis reaction in the exothermic side and dehydrogenation of cyclohexane in the endothermic side has been modified using a hydrogen perm-selective membrane as the shell of the reactor to separate the produced hydrogen from the dehydrogenation process. Permeated hydrogen enters another section called permeation side to be collected by argon, known as the sweep gas. This three-sided reactor has been optimized using differential evolution (DE) method to predict the conditions at which the reactants' conversion and also the hydrogen recovery yield would be maximized. Minimizing the CO_2 and CH_4 yield in the reactor's outlet as undesired products is also considered in the optimization process. To reach this goal, optimal initial molar flow rate and inlet temperature of three sides as well as pressure of the exothermic side have been calculated. The obtained results have been compared with the conventional reactor data of the Research Institute of Petroleum Industry (RIPI), the membrane dual-type reactor suggested for Fischer–Tropsch synthesis, and the membrane coupled reactor presented for methanol synthesis. The comparison shows acceptable enhancement in the reactor's performance and that the production of hydrogen as a valuable byproduct should also be considered.

12/00580 Sulfur removal from hydrotreated petroleum fractions using ultrasound-assisted oxidative desulfurization process
Duarte, F. A. *et al. Fuel*, 2011, 90, (6), 2158–2164.
Ultrasound-assisted oxidative desulfurization (UAOD) process was applied to diesel oil and petroleum product feedstock containing model sulfur compounds (benzothiophene, dibenzothiophene and dimethyldibenzothiophene). The influence of oxidant amount, volume of solvent for the extraction step and time and temperature of ultrasound treatment (20 kHz, 750 W, operating at 40%) was investigated. Using the optimized conditions for UAOD, sulfur removal up to 99% was achieved for model compounds in petroleum product feedstock using a molar proportion for H_2O_2 : acetic acid : sulfur of 64 : 300 : 1, after 9 min of ultrasound treatment at 90 °C, followed by extraction with methanol (optimized solvent and oil ratio of 0.36). Using the same reagent amount and 9 min of ultrasound the removal of sulfur was higher than 75% for diesel oil samples. Sulfur removal without ultrasound using the same conditions was lower than 82% for model compounds and 55% for diesel oil samples showing that ultrasound improved the efficiency of oxidative desulfurization. In comparison to conventional hydrodesulfurization, the proposed UAOD process can be performed under relatively mild conditions (atmospheric pressure and 90 °C, without using metallic catalysts).

Economics, business, marketing, policy

12/00581 Anticipated and unanticipated effects of crude oil prices and gasoline inventory changes on gasoline prices
Radchenko, S. and Shapiro, D. *Energy Economics*, 2011, 33, (5), 758–769.
This paper examines the effect of anticipated and unanticipated changes in oil prices and gasoline inventory on US gasoline prices. The authors estimated empirical responses to anticipated and unanticipated changes in oil prices and gasoline inventory and show that gasoline price adjustments are faster and stronger for anticipated changes in oil prices and inventory levels than for unanticipated changes. Furthermore, this difference is statistically significant. The findings are used to evaluate the cost of adjustment hypothesis suggested by earlier studies. It was also found that there is an asymmetry in the effect of gasoline inventory on gasoline and oil prices. This finding complements a well-known result that positive and negative changes in oil prices have asymmetric effect on gasoline prices.

12/00582 Co-optimization of enhanced oil recovery and carbon sequestration
Leach, A. *et al. Resource and Energy Economics*, 2011, 33, (4), 893–912.
This paper presents an economic analysis of CO_2-enhanced oil recovery (EOR). This technique entails injection of CO_2 into mature oil fields in a manner that reduces the oil's viscosity, thereby enhancing the rate of extraction. As part of this process, significant quantities of CO_2 remain sequestered in the reservoir. If CO_2 emissions are regulated, oil producers using EOR should therefore be able to earn revenues from sequestration as well as from oil production. The authors develop a theoretical framework that analyses the dynamic co-optimization of oil extraction and CO_2 sequestration, through the producer's choice of the fraction of CO_2 in the injection stream at each moment. They find that the optimal fraction of CO_2 is likely to decline monotonically over time, and reach zero before the optimal termination time. Numerical simulations, based on an on-going EOR project in Wyoming, confirm this result. They also find that cumulative sequestration is less responsive to the carbon tax than to the oil price. Only at very high taxes does a trade-off between revenues from oil output and sequestration arise.

12/00583 Crude oil shocks and stock markets: a panel threshold cointegration approach
Zhu, H.-M. *et al. Energy Economics*, 2011, 33, (5), 987–994.
This paper proposes a panel threshold cointegration approach to investigate the relationship between crude oil shocks and stock markets for the OECD and non-OECD panel from January 1995 to December 2009. Non-linear cointegration is confirmed for the oil–stock nexus in the panel. Because threshold cointegration is found, the threshold vector error correction models can be run to investigate the presence of asymmetric dynamic adjustment. The Granger causality tests demonstrate the existence of bidirectional long-run Granger causality between crude oil shocks and stock markets for these OECD and non-OECD countries. However, the short-run Granger causality between them is bidirectional under positive changes in the deviation and unidirectional under negative ones. Moreover, the speed of adjustment toward equilibrium is faster under negative changes in the deviation than that under positive ones in these OECD and non-OECD countries.

12/00584 Diesel and rapeseed methyl ester (RME) pilot fuels for hydrogen and natural gas dual-fuel combustion in compression–ignition engines
Korakianitis, T. *et al. Fuel*, 2011, 90, (7), 2384–2395.
This paper presents experimental results of rapeseed methyl ester (RME) and diesel fuel used separately as pilot fuels for dual-fuel compression–ignition (CI) engine operation with hydrogen gas and natural gas (the two gaseous fuels are tested separately). During hydrogen dual-fuel operation with both pilot fuels, thermal efficiencies are generally maintained. Hydrogen dual-fuel CI engine operation with both pilot fuels increases NO_x emissions, while smoke, unburnt HC and CO levels remain relatively unchanged compared with normal CI engine operation. During hydrogen dual-fuel operation with both pilot fuels, high flame propagation speeds in addition to slightly increased ignition delay result in higher pressure-rise rates, increased emissions of NO_x and peak pressure values compared with normal CI engine operation. During natural gas dual-fuel operation with both pilot fuels, comparatively higher unburnt HC and CO emissions are recorded

compared with normal CI engine operation at low and intermediate engine loads which are due to lower combustion efficiencies and correspond to lower thermal efficiencies. This could be due to the pilot fuel failing to ignite the natural gas–air charge on a significant scale. During dual-fuel operation with both gaseous fuels, an increased overall hydrogen–carbon ratio lowers CO_2 emissions compared with normal engine operation. Power output (in terms of brake mean effective pressure, BMEP) as well as maximum engine speed achieved are also limited. This results from a reduced gaseous fuel induction capability in the intake manifold, in addition to engine stability issues (i.e. abnormal combustion). During all engine operating modes, diesel pilot fuel and RME pilot fuel performed closely in terms of exhaust emissions. Overall, CI engines can operate in the dual-fuel mode reasonably successfully with minimal modifications. However, increased NO_x emissions (with hydrogen use) and incomplete combustion at low and intermediate loads (with natural gas use) are concerns; while port gaseous fuel induction limits power output at high speeds.

12/00585 Economic impacts and challenges of China's petroleum industry: an input–output analysis

Xu, T. *et al. Energy*, 2011, 36, (5), 2905–2911.

It is generally acknowledged that the petroleum industry plays an important role in China's national economic and social development. The direct, indirect, and induced impacts of China's petroleum industry are analysed in this study by using the input–output approach. The study also considers the main challenges that China's economy might face in the future. The research results suggest the following. (1) The total economic impacts coefficients on output, given each unit of final demands change in extraction of petroleum and processing of petroleum, are 1.9180 and 3.2747 respectively, and the corresponding economic impacts coefficients on GDP are 1.0872 and 0.9001 respectively. (2) Extraction of petroleum has a more direct impact on GDP, while processing of petroleum has a greater effect on the total output. (3) Extraction of petroleum's total economic impacts coefficients on both output and GDP have remained stable in recent years after a period of long decline; processing of petroleum's total economic impacts coefficient on output is steadily increasing. (4) Import uncertainty, the likelihood of rising oil prices, and net oil exports caused by items manufactured with petroleum products (i.e. 'Made in China' goods) are the main challenges the petroleum industry will cause for China's overall economy.

12/00586 Examining crude oil price – exchange rate nexus for India during the period of extreme oil price volatility

Ghosh, S. *Applied Energy*, 2011, 88, (5), 1886–1889.

This study probes crude oil price – exchange rate nexus for India using daily data for the period 2 July 2007 to 28 November 2008. Generalized autoregressive conditional heteroskedasticity (GARCH) and exponential GARCH (EGARCH) models have been employed to examine the impact of oil price shocks on nominal exchange rate. The study reveals that an increase in the oil price return leads to the depreciation of Indian currency *vis-à-vis* the US dollar. The study also establishes that positive and negative oil price shocks have similar effects, in terms of magnitude, on exchange rate volatility and oil price shocks have permanent effect on exchange rate volatility.

12/00587 Joint stockpiling and emergency sharing of oil: arrangements for regional cooperation in East Asia

Shin, E.-S. and Savage, T. *Energy Policy*, 2011, 39, (5), 2817–2823.

The East Asia region includes three of the world's top five oil-importing nations: China, Japan, and the Republic of Korea. As a consequence, international oil supply disruptions and oil price spikes, and their effects on the economies of the region, have historically been of significant concern. Each of these three nations, as well as other nations in East Asia, has developed or is developing their own strategic oil stockpiles, but regional coordination in stockpiling arrangements and sharing of oil stocks in an emergency could provide significant benefits. This article describes the overall oil supply security situation in East Asia, reviews the attributes of different stockpiling arrangements to address energy supply security concerns, summarizes on-going national approaches to stockpiling in East Asia, describes the development of joint oil stockpile initiatives in the region, and suggests the most attractive options for regional co-operation on oil stockpiling issues.

12/00588 Major challenges of offshore platforms design for shallow water oil and gas field in moderate ice conditions

Zhang, D. and Yue, Q. *Ocean Engineering*, 2011, 38, (10), 1220–1224.

Offshore engineers and scientists face fascinating economical and technical challenges in designing offshore platforms for shallow water oil and gas fields in moderate ice conditions. Petroleum production systems in these ice-infested areas such as the Bohai Bay of China, Cook Inlet, Barent Sea, and Caspian Sea must be designed to accommodate the harsh environmental conditions, among which the first-year sea ice is one of the major design consideration. Extreme ice loads and ice-induced vibrations still remain an area of uncertainty in offshore platforms. This paper demonstrates the main technical aspects on the use of jackets in the Bohai Bay, with particular focus on ice loads and the failure modes of slender ice-resistant structures, which are the two key issues in design considerations. A design proposal and some considerations for economical ice-resistant structures for safe development in the cold region are also conceptually discussed.

12/00589 Minimum variance hedging with bivariate regime-switching model for WTI crude oil

Hung, J.-C. *et al. Energy*, 2011, 36, (5), 3050–3057.

This paper proposes a four-regime bivariate Markov regime-switching model to estimate the daily time-varying minimum variance hedge ratios for West Texas Intermediate (WTI) crude oil, and evaluates its in- and out-of-sample hedging performances with two-regime model, CC-GARCH, TVC-GARCH, and OLS models. Empirical results reveal that the four-regime Markov switching model outperforms the other models for both in- and out-of-sample hedging performance. Based on Hansen's SPA test, the four-regime model significantly outperforms the other models for only in-sample hedging.

12/00590 Opportunities and challenges for biodiesel fuel

Lin, L. *et al. Applied Energy*, 2011, 88, (4), 1020–1031.

Fossil fuel resources are decreasing daily. As a renewable energy, biodiesel has been receiving increasing attention because of the relevance it gains from the rising petroleum price and its environmental advantages. This review highlights some of the perspectives for the biodiesel industry to thrive as an alternative fuel, while discussing opportunities and challenges of biodiesel. This review is divided in three parts. First overview is given on developments of biodiesel in past and present, especially for the different feedstocks and the conversion technologies of biodiesel industry. More specifically, an overview is given on possible environmental and social impacts associated with biodiesel production, such as food security, land change and water source. Further emphasis is given on the need for government's incentives and public awareness for the use and benefits of biodiesel, while promoting policies that will not only endorse the industry, but also promote effective land management.

12/00591 Revisiting the relationship between spot and futures oil prices: evidence from quantile cointegrating regression

Lee, C.-C. and Zeng, J.-H. *Energy Economics*, 2011, 33, (5), 924–935.

Since most real decisions depend upon current market states or whether it is advantageous to the participants themselves, this paper revisits the relationship between spot and futures oil prices of West Texas Intermediate covering 1986 to 2009 with an innovative approach named quantile cointegration. In contrast to previous perspectives, the authors target the issues of cointegrating relationships, causalities, and market efficiency based on different market states under different maturities of oil futures. In this empirical analysis, except for market efficiency, long-run cointegrating relationships and causalities between spot and futures oil prices have significant differentials among futures maturities and the performances of spot oil markets. Furthermore, the response of spot prices to shocks in 1-month futures oil prices is much steeper in high spot prices than in low spot prices. This phenomenon is consistent with the prospect theory, in that the value function is generally steeper for losses than for gains.

12/00592 The current status of liquid biofuels in Chile

García, A. E. *et al. Energy*, 2011, 36, (4), 2077–2084.

Chile depends on foreign sources for energy. A solution for this problem is needed to guarantee stability and economic development. Public policies have been proposed involving diversification of the power matrix with an increasing share for non-conventional renewable energies (NCRE) from unconventional resources in the medium and long term. In this framework, new funding strategies are fundamental to encourage applied research in this field. Main research subjects are considered: survey, quantification and characterization of raw materials, introduction of energy crops and studies focused on transportation, management and conversion of lignocellulose for the second-generation biofuel industry. A recent regulatory framework allows the substitution of 2% or 5% of gasoline and diesel by ethanol and biodiesel, respectively; however, this is not mandatory because biofuel supply is still non-secured. On the other hand, the scenario for private initiatives focused on first-generation biofuels is not promising, and this may continue in time depending on the price of imported biofuels and local production costs. In 2015, production of second-generation biodiesel in Chile should be fundamentally based on forestry residues using Fischer–Tropsch processes. Local efforts consider biochemical transformation of lignocelluloses including agricultural wastes. The group is focused on optimization of local second-generation bioethanol production; preliminary results are presented here.

12/00593 The energy efficiency of crude oil refining in Brazil: a Brazilian refinery plant case
de Lima, R. S. and Schaeffer, R. *Energy*, 2011, 36, (5), 3101–3112.
This article evaluates energy efficiency in Brazilian crude oil refining in comparison with the crude oil refining in the USA between 1930 and 2008. It aims to show that increased refinery complexity reduces the energy consumption of products of high value added. Moreover, the article shows that improvements in energy efficiency result in higher quality products and increased processing of oil. A Brazilian refinery with a capacity of 157,000 barrels per day (kbpd) was modernized in 2008 at a cost of US$1.3 billion. As a result, its capacity increased by 17%, from 157 to 189 kbpd. Its complexity index also rose from 3.2 to 6.8, allowing an improvement in the EII (energy intensity index) from 110% to 93%. In relation to the crude oil processed before being modernized, energy consumption fell from 0.75 to 0.52 MBtu (million British thermal units) per barrel processed. These proceedings show that increases in complexity reduce the energy consumed in the production of final products with high value added, such as gasoline, diesel and jet fuel.

Derived liquid fuels

12/00594 Co-liquefaction of Makarwal coal and waste polystyrene by microwave–metal interaction pyrolysis in copper coil reactor
Hussain, Z. *et al. Journal of Analytical and Applied Pyrolysis*, 2011, 90, (1), 53–55.
A novel method for the co-pyrolysis of waste polystyrene with coal was investigated. This method is based on high temperature obtained by microwave copper interaction. This pyrolysis is believed to be the combine action of the high temperature, microwaves interaction and the active species produced during the process. The metal antenna may also catalyse the pyrolysis process and affect the nature of products. This is a faster method of the co-pyrolysis and gives 66% oily liquid which was a mixture of tar and oil, 10% aqueous liquid mainly composed of sulfides, 6% gases and 18% residues. The liquid product was collected using cold traps and the amount of gas was obtained by taking difference. The oily liquid product was analysed using GC–MS and found that it contains mainly aromatic compounds in a narrow range. The range of products and product formation is also discussed in this communication.

12/00595 Conversion of refinery natural purge gases to liquid hydrocarbons in GTL loop with hydrogen-permselective membranes: an alternative to gas flaring
Rahimpour, M. R. *et al. Journal of Natural Gas Science and Engineering*, 2011, 3, (3), 461–475.
In the present work, a novel gas-to-liquid (GTL) loop is proposed to convert the natural gas wasted by a gas refinery to higher molecular weight hydrocarbons. The process proposes an alternative method that, instead of conventional gas-burning flares, aims to minimize CO_2 emissions and produce liquid fuel such as gasoline. For this purpose, purged natural gas is converted to synthesis gas in a novel hydrogen-permselective membrane reactor with recycle stream and then it is converted to liquid fuel in Fischer–Tropsch membrane reactor. In this configuration, a loop is constructed by returning and mixing a portion of the product with the original feed through a recycle stream. This approach produces large amounts of higher molecular weight hydrocarbons, hydrogen production and decreases environmental impacts owing to purge gases emission. The simulation results of the aforesaid loop, show decrease in CO_2 emission rate with a value of 1/10 to that of flaring with production of 0.018 kgmol/s of hydrogen and more than 90 barrels per day of heavy fraction hydrocarbons containing gasoline and butane fraction for a specified value of (about 4 MMscfd) purge gases.

12/00596 Field validation of pressure drop models in perforated section of gas condensate wells
Firoozabadi, H. M. *et al. Journal of Natural Gas Science and Engineering*, 2011, 3, (2), 375–381.
Oil and gas flow from the reservoir to the wellbore via perforated sections of the well. Various models are available in the literature to simulate the relation between the flow rate and pressure drop in this section of the wells. These models are developed and tested in the laboratory, but validation of them in field applications is questionable. This problem is more noticeable in complex cases such as gas condensate wells. In this research, field data for gas condensate wells were used to verify the validity of different methods for calculation of pressure drop in the perforated sections of the pipes. The calculations showed the accuracy of different available methods to calculate pressure drop in gas condensate wells.

12/00597 Hydrogen as an energy carrier: a comparative study between decalin and cyclohexane in thermally coupled membrane reactors in gas-to-liquid technology
Rahimpour, M. R. *et al. International Journal of Hydrogen Energy*, 2011, 36, (12), 6970–6984.
The feasibility of decalin as a promising hydrogen carrier is investigated in this study. The performance of a decalin thermally coupled membrane reactor (DCTCMR) is compared with a cyclohexane thermally coupled membrane reactor (CTCMR) for Fischer–Tropsch synthesis (FTS) in gas-to-liquid (GTL) technology. Some important parameters such as hydrogen production rate, H_2 recovery yield, exothermic and endothermic temperature profiles, etc. are considered as criteria to recognize the most appropriate configuration. A comparison between the modelling results of two coupled configurations shows that DCTCMR is superior to CTCMR owing to achieving remarkably higher hydrogen production (17 times) compared with CTCMR. Furthermore, considerably higher H_2 recovery yield (about 12 times) and faster dehydrogenation reaction rate in DCTCMR than CTCMR proposes decalin as one of the best hydrogen carriers. This study demonstrates the superiority of DCTCMR to CTCMR owing to achieving remarkably higher hydrogen production rate, H_2 recovery yield and recognizing decalin as an appropriate hydrogen carrier.

12/00598 Liquefaction of Shengli lignite with methanol and CaO under low pressure
Lei, Z. *et al. Energy*, 2011, 36, (5), 3058–3062.
The behaviour of liquefaction of Shengli (SL) lignite with methanol and CaO in the presence of FeS and tetralin (THN) was studied. The effects of reaction temperature and time on the liquefaction behaviour of SL lignite with methanol and CaO were preliminarily investigated. The liquefaction products obtained were analysed by FTIR spectrum and elemental analysis. The results show that SL lignite liquefaction with methanol and CaO in the presence of FeS is one of the feasible liquefaction methods. This method has some advantages such as the higher liquefied product yields and n-hexane soluble (HS) + gas yield compared to that of liquefaction in H_2 atmosphere; and carrying out at lower pressure, which was only one third of that of liquefaction in H_2 initial pressure of 5 MPa. The reaction temperature and time significantly affect the liquefied product yields and distributions. The lignite liquefied product yield and gas + HS yield reach to 81.8% and 62% respectively at 400 °C for 2 h, which are significantly higher than those of liquefaction in H_2 initial pressure 5 MPa.

12/00599 Liquid fuel from castor seeds by pyrolysis
Singh, R. K. *et al.* Shadangi, K. P. *Fuel*, 2011, 90, (7), 2538–2544.
Bio-energy is now considered as having the potential to provide the major part of the projected renewable energy provisions of the future. Slow pyrolysis is one of the three main thermal routes, with gasification and combustion, for providing a useful and valuable bio-fuel. Slow thermal pyrolysis of castor seeds were carried out in a semi batch reactor made up of stainless steel at temperature range from 450 to 600 °C to produce bio-fuel. This paper studied the effect of temperature on pyrolysis of castor seeds to find the optimum temperature of maximum liquid yield. The thermal degradation temperature of castor seed was studied using thermogravimetric analysis (TGA) at a heating rate of 20 °C/min in air atmosphere. The oil samples obtained at optimum condition is analysed according to their fuel properties, elemental analysis, functional group presents, and compounds presents.

12/00600 Techno-economic evaluation of coal-to-liquids (CTL) plants with carbon capture and sequestration
Mantripragada, H. C. and Rubin, E. S. *Energy Policy*, 2011, 39, (5), 2808–2816.
Coal-to-liquids (CTL) processes that generate synthetic liquid fuels from coal are of increasing interest in light of the substantial rise in world oil prices in recent years. A major concern, however, is the large emissions of CO_2 from the process, which would add to the burden of atmospheric greenhouse gases. To assess the options, impacts and costs of controlling CO_2 emissions from a CTL plant, a comprehensive techno-economic assessment model of CTL plants has been developed, capable of incorporating technology options for carbon capture and storage (CCS). The model was used to study the performance and cost of a liquids-only plant as well as a co-production plant, which produces both liquids and electricity. The effect of uncertainty and variability of key parameters on the cost of liquids production was quantified, as were the effects of alternative carbon constraints such as choice of CCS technology and the effective price (or tax) on CO_2 emissions imposed by a climate regulatory policy. The efficiency and CO_2 emissions from a co-production plant also were compared to the separate production of liquid fuels and electricity. The results for a 50,000 barrels/day case study plant are presented.

12/00601 Techno-economic evaluation of thermo-chemical biomass-to-ethanol
He, J. and Zhang, W. *Applied Energy*, 2011, 88, (4), 1224–1232.
Bio-ethanol has received considerable attention as a basic chemical and fuel additive. Bio-ethanol is presently produced from sugar/starch materials, but can also be produced from lignocellulosic biomass via hydrolysis-fermentation route or thermo-chemical route. In terms of thermochemical route, a few pilot plants ranging from 0.3 to 67 MW have been built and operated for alcohols synthesis. However, commercial success has not been found. In order to realize cost-competitive commercial ethanol production from lignocellulosic biomass through thermochemical pathway, a techno-economic analysis needs to be done. In this paper, a thermochemical process is designed, simulated and optimized mainly with ASPEN Plus. The techno-economic assessment is made in terms of ethanol yield, synthesis selectivity, carbon and CO conversion efficiencies, and ethanol production cost. Calculated results show that major contributions to the production cost are from biomass feedstock and syngas cleaning. A biomass-to-ethanol plant should be built around 200 MW. Cost-competitive ethanol production can be realized with efficient equipment, optimized operation, cost-effective syngas cleaning technology, inexpensive raw material with low pretreatment cost, high performance catalysts, off-gas and methanol recycling, optimal systematic configuration and heat integration, and high value byproduct.

03 GASEOUS FUELS

Sources, properties, recovery, treatment

12/00602 Behavior of gas production from Type III hydrate reservoirs
Zatsepina, O. *et al. Journal of Natural Gas Science and Engineering*, 2011, 3, (3), 496–504.
A large number of studies are underway to evaluate the possible role of gas hydrates as a potential energy resource. One class of such studies involves the development and use of mathematical models to (i) estimate the rate of gas production from hydrate reservoirs under different operating conditions, and (ii) better understand the role of different parameters in hydrate decomposition. A number of researchers have already studied gas production from hydrate reservoirs that had an underlying free-gas phase (type I). Similarly, hydrate reservoirs that totally lie within the hydrate stability zone and are located between impermeable layers on top and bottom (type III) have received significant attention. In this study, a numerical simulation approach is used to investigate gas production from type III hydrate reservoirs. A number of mechanistic and sensitivity studies have been conducted to better understand the factors controlling the rate of gas production. It is shown that the ability to decompose hydrates at a significant rate not only depends on the rate of heat transfer (as in type I reservoirs), but also on the ability of the formation to allow fluid flow (this is a much less important factor for type I reservoirs). In this work, the interaction between fluid flow and heat transfer is explored, and conditions that would allow significant gas production rate are illustrated. The challenges in the numerical modelling of type III hydrate reservoirs are also discussed.

12/00603 Investigating the effect of sorption time on coalbed methane recovery through numerical simulation
Ziarani, A. S. *et al. Fuel*, 2011, 90, (7), 2428–2444.
The objective of this work is to study the effect of non-equilibrium sorption time on the gas production rate in coalbed methane (CBM) reservoirs. Numerical simulation is employed to investigate this phenomenon in coal seams with single-phase flow of methane and two-phase flow of methane and water. Radial and rectangular models with vertical and horizontal wells are considered. A multi-layered model is also generated with properties similar to the Horseshoe Canyon (HSCN) formation in Alberta. The results indicate that the sorption time affects the production rate in the early production phase, namely a few months to a few years depending on how slow the desorption/diffusion process is, but this depends on the magnitude of the sorption time. This is valid both for dry and initially water saturated coalbed methane reservoirs. However, in the latter case, the effect lasts longer since the dewatering must occur first for desorption/diffusion process to start. The type of wellbore also influences the dynamics of sorption/diffusion effects. For smaller diffusion coefficients (larger sorption times), the gas decline rate in horizontal wells is larger relative to vertical wells. The results of the multi-layer study indicate that when sorption time is smaller than 10 days, the effect of sorption/diffusion phenomena on total commingled production rate is negligible. In general, the authors recommend non-equilibrium models for early-time production when diffusion flow from matrix to fracture is still in transient state. For late-time production, when steady-state diffusion flow has been established between matrix and fracture, equilibrium models can be used.

12/00604 Production behavior of methane hydrate in porous media using huff and puff method in a novel three-dimensional simulator
Li, G. *et al. Energy*, 2011, 36, (5), 3170–3178.
The gas production behaviour of methane hydrate in porous media using the huff and puff method was investigated in the cubic hydrate simulator (CHS), a novel developed three-dimensional 5.8-L cubic pressure vessel. Three horizontal layers equally divide the CHS into four regions. A nine-spot distribution of the vertical wells, a single horizontal well and a 25-spot distribution of the thermometers are arranged on each layer, respectively. The vertical wells at the axis of the CHS were used as the injection and production wells. The huff and puff method includes the injection, soaking and production stages. The amount of water injected and produced, the gas production rate, the percentage of the hydrate dissociation and the gas-to-water ratio were evaluated. Under the thermodynamic conditions in this work, the gas production from the sediment in this work using the huff and puff method is economically profitable from the relative criterion point of view. The sensitivity analysis demonstrates the dependence of the gas production on the initial hydrate saturation, and the temperature and the injection rate of the injected hot water.

12/00605 Regulating hydraulic fracturing in shale gas plays: the case of Texas
Rahm, D. *Energy Policy*, 2011, 39, (5), 2974–2981.
The ability to economically produce natural gas from unconventional shale gas reservoirs has been made possible recently through the application of horizontal drilling and hydraulic fracturing. This new technique has radically changed the energy future of the USA. The USA has shifted from a waning producer of natural gas to a growing producer. The Energy Information Administration forecasts that by 2035 nearly half of US natural gas will come from shale gas. Texas is a major player in these developments. Of the eight states and coastal areas that account for the bulk of US gas, Texas has the largest proved reserves. Texas's Barnett Shale already produces 6% of the continental USA's gas and exploration of Texas's other shale gas regions is just beginning. Shale gas production is highly controversial, in part because of environmental concerns. Some US states have put hydraulic fracturing moratoriums in place because of fear of drinking water contamination. The federal government has become involved and some states, like Texas, have accused it of over-reaching. The contention over shale gas drilling in the USA may be a bellwether for other parts of the world that are now moving forward with their own shale gas production.

12/00606 Sorption of methane on lignite from Polish deposits
Macuda, J. *et al. International Journal of Coal Geology*, 2011, 87, (1), 41–48.
Coal samples from Miocene lignite deposits (ortholignite – ECE-UN 2002) in Belchatow, Adamow, Konin and Turow (Poland) were analysed to determine the relationships between coal properties and gas capacity. Investigations presented here addressed the occurrence of methane sorbet in lignite deposits within Poland's largest penetrated lignite deposits (e.g. Belchatow, Adamow, Turow and Konin). Lignite samples collected from surface mines were detritic coal with variable contents of xylites. The highest level of xylites (up to 25 vol.%) was found in carbon samples taken from the Belchatow deposit. Samples from other mines contained no more than 10 vol.% xylites. Petrographic compositions were dominated by huminite group macerals (73–88 vol.%) with atrinite, densinite and texto-ulminite, a porous form of ulminite; inertinite groups were less important components (4–8 vol.%). Isotherms were determined for methane sorption at 298 K with test pressure ranges below 1.2 MPa. At a pressure of 1.0 MPa, the largest gas capacity of approximately 1.7 [dm^3 STP/kg] was found in the sample from Belchatow. This result may have been attributable to differences in the porosity of the samples; the porosity of the sample from Belchatow was twice as high as the porosities of the other coal samples. This variation in porosity resulted from the lithologic and maceral composition of the coal sample that contained substantial quantities of porous textinite and texto-ulminite. The thermal sorption equation was used to determine the limiting values of isosteric enthalpy of sorption, which suggested weak interactions between methane and the lignite matrix. The residual gas capacity of the tested samples was also determined. All samples exhibited a high residual methane-

bearing capacity, which may not only cause methane to be released from coal at a pressure of 1 bar but also may pose a gas risk during mining operations.

12/00607 1000 m long gas blow-out pipes

Løseth, H. *et al. Marine and Petroleum Geology*, 2011, 28, (5), 1047–1060.

This study presents seismic observation of pipe anomalies from offshore Nigeria, outcrops of blow-out pipes from Rhodes, Greece, and geophysical modelling of an acoustic pipe. The studies give insight into how pipes form, their internal structure, the seismic image and geophysical artefacts related to the pipes. Over 100 seafloor craters, 100–700 m wide and up to 30 m deep, have been observed on the seafloor offshore Nigeria. They are underlain by interpreted cones and seismic pipe anomalies that can be traced down to reservoir zones at 1000–1300 m below the seafloor. The seismic pipe anomalies are 50–150 m wide and almost vertical. They are interpreted as up-scaled pipes found in outcrops on Rhodes, Greece. The outcrops show pipe-related structures at three levels. Lowest, the reservoir rock contains metre-sized cavities which are filled with a mixture of clay derived from the overlying cap rock. In the middle, several circular to oval structures in plane view of pipes are observed in the lowest part of the cap rock. Highest, 15 m into the clay cap rock, strongly sheared country rock forms circular structures with a core of structureless clay. Based on outcrop observation on Rhodes, an acoustic model of a 50 m wide and 1000 m long pipe was constructed. Seismic modelling proves that such pipes would be expressed in seismic data, that they are similar to the seismic pipe anomalies offshore Nigeria but this study also revealed that prominent intra-pipe reflections are artefacts. A formation model for the pipes is suggested: high fluid overpressure in the reservoir generated hydro fractures from the reservoir to seafloor where a mixture of gas and fluid flowed at high speed to form pipes, cones and seafloor craters. After hours to weeks of gas and fluid flow through the pipe the pore pressure in the reservoir dropped and the blow-out terminated. Muddy slurry fell back and plugged the cavity in the reservoir and the pipe.

Transport, storage

12/00608 Contact angles in CO_2-water-coal systems at elevated pressures

Sakurovs, R. and Lavrencic, S. *International Journal of Coal Geology*, 2011, 87, (1), 26–32.

Injection of carbon dioxide into coal seams is considered to be a potential method for its sequestration away from the atmosphere. However, water present in coals may retard injection: especially if carbon dioxide does not wet the coal as well as water. Thus contact angles in the coal–water–CO_2 system were measured using CO_2 bubbles in water–coal systems at 40 °C and pressures up to 15 MPa using five bituminous coals. At low pressures, in this CO_2–water–coal system, receding contact angles for the coals ranged between 80° to 100°; except for one coal that had both high ash yield and low rank, with a contact angle of 115°, indicating that it was hydrophilic. With increasing pressure, the receding contact angles for the different coals decreased, indicating that they became more CO_2-wetting. The relationship between contact angle and pressure was approximately linear. For low ash or high rank coals, at high pressure the contact angle was reduced to 30–50°, indicating the coals became strongly CO_2-wetting; that is CO_2 fluids will spontaneously penetrate these wet coals. In the case of the coal that was both high ash and hydrophilic, the contact angle did not drop to 90° even at the highest pressures used. These results suggest that CO_2 will not be efficiently adsorbed by all wet coals equally well, even at high pressure. It was found that at high pressures (>2 MPa) the rate of penetration of carbon dioxide into the coals increased rapidly with decreasing contact angle, independently of pressure. Injecting CO_2 into wet coals that have both low rank and high ash will not trap CO_2 as well as injecting it into high rank or low ash coals.

12/00609 Determining the corrosive potential of CO_2 transport pipeline in high pCO_2–water environments

Choi, Y.-S. and Nešić, S. *International Journal of Greenhouse Gas Control*, 2011, 5, (4), 788–797.

The corrosive potential of carbon steel was evaluated under high pressure CO_2–water systems to simulate the condition of CO_2 transportation pipeline in the CO_2 capture and storage (CCS) applications. To understand the thermodynamic properties of CO_2–water systems related to the corrosion phenomena, thermodynamic modelling were conducted to determine the mutual solubilities of CO_2 and water in the two coexisting phases, and to calculate the concentrations of corrosive species in the free water at various pressures and temperatures. Carbon steel samples were exposed to water-saturated CO_2, and CO_2-saturated water in the CO_2 pressure range of 40–80 bar at 50 °C. The corrosion rate of samples was determined by weight loss measurements. The surface morphology and the composition of the corrosion product layers were analysed by using surface analytical techniques (SEM and EDS).

12/00610 Exergy-based analysis of gas transmission system with application to Yamal-Europe pipeline

Chaczykowski, M. *et al. Applied Energy*, 2011, 88, (6), 2219–2230.

This paper presents a thermodynamic analysis of a gas transmission system consisting compressor stations and pipeline sections. It has been assumed that the compressor station comprises a gas turbine-driven compressor and a gas cooler, and the irreversibility of the processes associated with the gas transmission was investigated. The exergy method was used to determine the amount of work supplied to the components of the pipeline system and the amount of work that is lost during the gas transmission. For the case study, the Yamal–Europe pipeline is chosen. In this study, a non-isothermal, steady-state gas flow model was used for comparing the performance of the gas transmission system under different cooler operating set points. The pipeline flow and the compressor station processes were governed by the equations which include real-gas model based on virial equation of state.

12/00611 First assessment of sources and sinks for carbon capture and geological storage in Portugal

Carneiro, J. F. *et al. International Journal of Greenhouse Gas Control*, 2011, 5, (3), 538–548.

A preliminary study for a source–sink match for application of carbon capture and storage (CCS) in Portugal is presented. The location of the main CO_2 emission sources in Portugal, existing and planned, was analysed and three main source clusters, emitting a total of 26.8 Mt/year, were defined. The three source clusters are connected by a natural gas pipeline network. CO_2 storage reservoirs are likely to be restricted to deep saline formations. Potential storage formations are described in the Porto, Lusitanian and Algarve sedimentary basins. Due to the large continental shelf, composed mainly of sedimentary rocks, it is important to consider offshore opportunities. A geographical information system (GIS), including information on the stratigraphy, seismicity, neotectonics and geothermal features, was used for prioritizing the areas where reservoir identification and characterization studies should be conducted. Despite not showing the most promising geological conditions, the area around the deepwater harbour of Sines is given the highest priority, since sources in the area account for more than 40% of point source emissions in Portugal.

12/00612 Integration of microseismic and other post-fracture surveillance with production analysis: a tight gas study

Clarkson, C. R. and Beierle, J. J. *Journal of Natural Gas Science and Engineering*, 2011, 3, (2), 382–401.

Quantitative production analysis of tight gas reservoirs has historically been a challenge due to complex reservoir characteristics, induced hydraulic fracture properties in vertical wells, operational complexities and data quality. All of these challenges conspire to make extraction of reservoir (kh and $OGIP$) and hydraulic fracture properties (x_f and fracture conductivity) solely from production/flowing pressure data difficult, often resulting in non-unique answers. Recently, there has been the added complication that tight gas (and shale gas) reservoirs are now being exploited with horizontal wells, often stimulated using multiple hydraulic fracture stages, which imparts greater complexity on the analysis. Flow regime identification, which is critical to the correct analysis, is more complicated than ever owing to the number of possible flow regimes encountered in such wells. A case study is presented in which it is demonstrated that modern post-fracture surveillance data, such as microseismic and post-frac production logging, aids in both model identification and model calibration, which is critical to the analysis of hydraulically-fractured horizontal wells completed in tight gas formations. A workflow is presented in which offset vertical wells (to the horizontal wells) are first analysed to obtain estimates of kh and hydraulic fracture properties, followed by commingled stage and single-stage production analysis of the multi-(transverse) hydraulic fracture horizontal wells. Microseismic data is incorporated into the analysis of the horizontal wells to: (1) understand the orientation and degree of complexity of the induced hydraulic fractures. and (2) constrain interpretations of effective hydraulic fracture lengths from production data analysis. It is also demonstrated that once the commingled stage analysis of the horizontal wells is completed, the total interpreted effective hydraulic fracture half-length may be allocated amongst the stages using a combination of production logs and tracer logs. The primary contribution of the current work is the presentation of workflows, emphasizing the integration of various data sources, to improve production analysis of multi-frac'd horizontal wells completed in tight gas formations. In addition to the workflows, it is shown that a combination of advanced production analysis

approaches, including methods analogous to classic pressure transient analysis, production type-curve matching and simulation, may be necessary to arrive at a unique analysis.

12/00613 Linear genetic programming to scour below submerged pipeline

Azamathulla, H. Md. *et al. Ocean Engineering*, 2011, 38, (8–9), 995–1000.

Genetic programming (GP) has nowadays attracted the attention of researchers in the prediction of hydraulic data. This study presents linear genetic programming (LGP), which is an extension to GP, as an alternative tool in the prediction of scour depth below a pipeline. The data sets of laboratory measurements were collected from published literature and were used to develop LGP models. The proposed LGP models were compared with adaptive neuro-fuzzy inference system (ANFIS) model results. The predictions of LGP were observed to be in good agreement with measured data, and quite better than ANFIS and regression-based equation of scour depth at submerged pipeline.

12/00614 Monitoring of CO_2 storage in a depleted natural gas reservoir: gas geochemistry from the CO2CRC Otway Project, Australia

Boreham, C. *et al. International Journal of Greenhouse Gas Control*, 2011, 5, (4), 1039–1054.

The CO2CRC Otway Project in south-western Victoria, Australia has injected over 17 months 65,445 tonnes of a mixed CO_2–CH_4 fluid into the water leg of a depleted natural gas reservoir at a depth of ~2 km. Pressurized sub-surface fluids were collected from the Naylor-1 observation well using a tri-level U-tube sampling system located near the crest of the fault-bounded anticlinal trap, 300 m up-dip of the CRC-1 gas injection well. Relative to the pre-injection gas–water contact (GWC), only the shallowest U-tube initially accessed the residual methane gas cap. The pre-injection gas cap at Naylor-1 contains CO_2 at 1.5 mol% compared to 75.4 mol% for the injected gas from the Buttress-1 supply well and its CO_2 is depleted in ^{13}C by 4.5‰ VPDB compared to the injected supercritical CO_2. Additional assurance of the arrival of injected gas at the observation well is provided by the use of the added tracer compounds, CD_4, Kr and SF_6 in the injected gas stream. The initial breakthrough of the migrating dissolved CO_2 front occurs between 100 and 121 days after CO_2 injection began, as evidenced by positive responses of both the natural and artificial tracers at the middle U-tube, located an average 2.3 m below the pre-injection GWC. The major CO_2 increase to ~60 mol% and transition from sampling formation water with dissolved gas to sampling free gas occurred several weeks after the initial breakthrough. After about another 3 months the CO_2 content in the lowest U-tube, a further average 4.5 m deeper, increased to approximately 60 mol%, similarly accompanied by a transition to sampling predominantly gases. Around this time, the CO_2 content of the upper U-tube, located in the gas cap and an average 10.4 m above the pre-injection GWC, increased to approximately 20 mol%. Subsequently, the CO_2 content in the upper U-tube approaches 30 mol% while the lower two U-tubes show a gradual decrease in CO_2 to approximately 48 mol%, resulting from mixing of injected and indigenous fluids and partitioning between dissolved and free gas phases. Lessons learnt from the CO2CRC Otway Project have enabled us to better anticipate the challenges for rapid deployment of carbon storage in a commercial environment at much larger scales.

12/00615 Preparing to ramp up large-scale CCS demonstrations: an engineering-economic assessment of CO_2 pipeline transportation in China

Liu, H. and Gallagher, K. S. *International Journal of Greenhouse Gas Control*, 2011, 5, (4), 798–804.

An integrated carbon dioxide (CO_2) capture and storage (CCS) system requires safe and cost-efficient solutions for transportation of the CO_2 from the capturing facility to the location of storage. While growing efforts in China are underway to understand CO_2 capture and storage, comparatively less attention has been paid to CO_2 transportation issues. Also, to the best of the authors' knowledge, there are no publicly available China-specific cost models for CO_2 pipeline transportation that have been published in peer-reviewed journals. This paper has been developed to determine a first-order estimate of China's cost of onshore CO_2 pipeline transportation. An engineering-economic model based on China-specific data, codes, and standards to the greatest extent possible has been developed for this purpose. Based on the model, five illustrative case studies on pipelines for transporting captured CO_2 from typical integrated gasification combined cycle (IGCC) and ultra-supercritical (USC) generating units of 250, 400, 660, 1000 and 2 × 1000 MW are carried out. The results show the capital costs of constructing a 100-km long pipeline are between $18 million and $102 million, depending on the amount of CO_2 transported. Corresponding figures for the levelized costs are $1.84–$3.06 per tonne of CO_2. Sensitivity analyses are also performed examining the effect of pipeline length and soil temperature on pipeline diameter, as well as flow rate and capital cost on levelized cost. The pipeline length is found to impact the diameter significantly, whereas soil temperature demonstrates insensitivity to pipeline diameter. Both flow rate and capital cost have significant effects on levelized cost. Comparison to other existing models based on either North American or European data implies a major cost difference between developed countries and China: China's cost of onshore CO_2 pipeline transportation is very likely much lower than those estimated in the developed countries. For a 0.02 $MtCO_2$/d case, for example, the levelized cost of CO_2 transportation in China is about two-thirds that of the developed countries.

Economics, business, marketing, policy

12/00616 An economic analysis of the production of hydrogen from wind-generated electricity for use in transport applications

Menanteau, P. *et al. Energy Policy*, 2011, 39, (5), 2957–2965.

Wind-generated electricity is often considered a particularly promising option for producing hydrogen from renewable energy sources. However, the economic performances of such systems generally remain unclear because of unspecified or favourable assumptions and operating conditions. The aim of this paper is to clarify these conditions by examining how the hydrogen produced is used. The analysis that has been conducted in the framework of the HyFrance 3 project concerns hydrogen for transport applications. Different technical systems are considered such as motorway hydrogen filling stations, Hythane®-fuelled buses or second-generation biofuels production, which present contrasted hydrogen use characteristics. This analysis reveals considerable variations in hydrogen production costs depending on the demand profiles concerned, with the most favourable configurations being those in which storage systems are kept to a minimum.

12/00617 CO_2 storage in a depleted gas field: an overview of the CO2CRC Otway Project and initial results

Underschultz, J. *et al. International Journal of Greenhouse Gas Control*, 2011, 5, (4), 922–932.

The Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) Otway Project in Australia is the first heavily monitored pilot site for CO_2 storage in a depleted natural gas reservoir. With the site characterization and risk analysis complete, the new CRC-1 injection well was drilled in April 2007. An updated static and dynamic model forecast an injected gas transit time of between 4 and 8 months between CRC-1 injection and Naylor-1 observation wells. Injection began on 18 March 2008 and was halted on 29 August 2009 with 65,445 tonnes of CO_2 mixed gas stored. Two pulses of tracer compounds were added to help identify the injected CO_2 from other naturally occurring CO_2 and to track dispersion and diffusion. Assurance monitoring included surveillance of the atmosphere, soil gas and shallow groundwater. To date, no tracer compounds have been detected above background levels in samples taken as part of the assurance monitoring system. Monitoring of the reservoir has been accomplished with a combined geophysical and geochemical approach. Formation fluids are sampled at pressure with the multilevel U-Tube system. The transient geochemistry at the observation well has: (1) recorded injected gas arrival at the Naylor-1 observation well; (2) recorded tracer compound arrival at Naylor-1; (3) shown a mixing trend between the isotopic signature of the Naylor indigenous CO_2 and that of the injection supply gas; and (4) provided an estimate for the dynamic storage capacity for a portion of the Naylor reservoir. The data collected are compared with the pre-injection dynamic model forecasts and provide a means of calibration. The CO2CRC Otway Project has successfully demonstrated the storage of CO_2 in a depleted gas field. Geochemical assurance monitoring and reservoir surveillance will continue post injection. Continued analysis of the data will serve to reduce uncertainty in forecasting the long-term fate of the injected CO_2 mixed gas.

12/00618 Household electricity and gas consumption for heating homes

Jeong, J. *et al. Energy Policy*, 2011, 39, (5), 2679–2687.

Energy consumption has been drastically changed because of energy source depletion, price fluctuations, development and penetration of alternative energy sources, and government policies. Household energy sources are interrelated, and energy price and household characteristics, such as income level and dwelling size, affect the usage. To supply energy consistently and achieve a balance between production and consumption, stakeholders must understand consumer energy-consumption behaviour. Therefore, this study identifies household heating energy usage patterns and the substitutive and/or complemen-

tary relationships between electricity and gas. Based on a multiple discrete-continuous extreme value model, household utility structure is identified from data on gas-heating usage. Results show greater utility and the smallest satiation values for gas boilers than for electric heaters and electric heating beds. The effects of consumer socioeconomic and environmental characteristics on the choice of heating energy sources were analysed. Also, for further comparison, the respondents were split into high and low categories for income, heating degree days, dwelling size, and gas usage. Gas was found to be the most economical heating choice for households.

12/00619 Identification of congestion and valuation of transport infrastructures in the European natural gas market

Lochner, S. *Energy*, 2011, 36, (5), 2483–2492.

Rising import dependency, increasing market liberalization and cross-border trade and security of supply fears facilitate investments in natural gas supply infrastructures in Europe. In order to ensure an efficient allocation of capital resources, it is important to identify congestion in the existing system and investment requirements based on economic principles. This paper first outlines an analytical framework for the identification of bottlenecks and the evaluation of transport capacities and the cost of congestion based on nodal prices. Secondly, an infrastructure model of the European gas market with high temporal and spatial granularity which exhibits the characteristics of the theoretical model is introduced. Parameterizing the model with the existing infrastructure and applying a demand and supply scenario for the year 2015, congestion mark-ups between countries in Europe are estimated. This approach indicates potential bottlenecks which might arise within the next 5 years and quantifies their economic costs. With only some temporary congestion, physical market integration is found to be high in Western Europe. In Eastern Europe, severe bottlenecks are identified and discussed. Implications for efficient investment decisions arising from the findings are examined in the context of the theoretical considerations.

12/00620 Investigations on the behaviour of 2 kW natural gas fuel processor

Di Bona, D. *et al. International Journal of Hydrogen Energy*, 2011, 36, (13), 7763–7770.

In this paper, initial experimental results on the performance of a pre-commercial fuel processor, selected to be integrated with a PEM fuel cell stack, in order to develop a high-efficiency microcogeneration unit fed by natural gas, have been presented. The aim of this experimental activity was both to study the behaviour of the reforming unit during its operation cycle and to investigate the critical operating conditions that can damage the fuel processing components (i.e. the catalysts activities and durability) and reduce the reformate gas quality (hydrogen concentration in the syngas or CO content). The experimental activity has been carried out in a versatile test station equipped by several measurements devices and a National Instruments Compact DAQ real-time data acquisition. The composition of the reformate gas has been analysed by an on-line gas chromatograph (7890A system, Agilent Technologies Inc.). The reformer has been tested at full and partial load operation. The comparison between the nominal and measured syngas compositions has pointed out that at full load these values are quite different because of the temperatures in the catalytic reactors (CO shift temperature is higher), while a better agreement is obtained at partial load. Another issue of the experimental activity was to analyse what kind of reformer failures can happen during its functioning, because the effects of irregular operations can have a negative impact both on fuel processor components and fuel cell stack performance and durability; in particular an irregular operation, caused by an uncontrolled increasing of temperature in the PROX reactor, has been analysed. Thus, these first experimental tests have pointed out the great importance in the control of the temperature of each catalytic reactor in order to guarantee a high hydrogen concentration in the reformate. A more detailed analysis on the reforming unit needs further experimental investigations that will be carried out in order both to evaluate the stability and durability of the reformer performance and estimate the effect of S/C ratio on the reformer efficiency.

12/00621 Potential for hydrogen generation from in situ combustion of Athabasca bitumen

Kapadia, P. R. *et al. Fuel*, 2011, 90, (6), 2254–2265.

The volume of heavy oil and bitumen in Alberta, Canada is estimated to be about 1.7 trillion barrels. The majority of the produced heavy oil and bitumen in Alberta is converted in surface upgraders to synthetic crude oil, a crude oil with API gravity typically between 31 and 33° API, which in turn can be converted to fuel, lubricant, and petrochemical products in standard refineries. To upgrade bitumen requires hydrogen. In current practice, much of this hydrogen is generated from catalytic steam reforming of methane together with the water–gas shift reaction. This means that heavy oil and bitumen upgrading, as is currently done, requires large amounts of natural gas to generate hydrogen. The potential for *in situ* generation of hydrogen by gasification of bitumen reservoirs offers an attractive alternative which can also have both economic and environmental benefits. For example, hydrogen generated from bitumen gasification can also be used for *in situ* upgrading as well as feedstock for ammonia and other chemicals. The water–gas shift reaction also generates carbon dioxide which could be potentially sequestered in an *in situ* gasification process so that emissions to the atmosphere are reduced. This technology provides a potential clean method to produce fuel and feedstock material from bitumen, a relatively 'dirty' fuel and feedstock oil, in addition to more energy efficient ways of extracting *in situ* heavy oils. However, to design *in situ* bitumen gasification processes requires a reaction model that provides a reasonable representation of the gasification reactions. Here, a new kinetic model is developed to examine the potential for hydrogen generation from Athabasca bitumen. The kinetic model consists of thermal cracking, oxidation/combustion, hydrogen generation and hydrogen consumption reactions. A comparison of the simulation results and experimental data from the published literature reveal that the new model can predict hydrogen generation from gasification of methane, Athabasca bitumen, and coke.

12/00622 Residential consumption of gas and electricity in the U.S.: the role of prices and income

Alberini, A. *et al. Energy Economics*, 2011, 33, (5), 870–881.

This study is concerned with the residential demand for electricity and gas, working with national household-level data that cover the years 1997–2007. The dataset is a mixed panel/multi-year cross-sections of dwellings/households in the 50 largest metropolitan areas in the USA as of 2008. The authors estimate static and dynamic models of electricity and gas demand. They found strong household response to energy prices, both in the short and long term. From the static models, estimates were obtained of the own price elasticity of electricity demand in the −0.860 to −0.667 range, while the own price elasticity of gas demand was −0.693 to −0.566. These results are robust to a variety of checks. Contrary to earlier literature, no evidence was found of significantly different elasticities across households with electric and gas heat. The price elasticity of electricity demand declined with income, but the magnitude of this effect was small. These results are in sharp contrast to much of the literature on residential energy consumption in the USA, and with the figures used in current government agency practice. The results suggest that there might be greater potential for policies which affect energy price than may have been previously appreciated.

12/00623 Risk in stability evaluation for floating offshore units

Vasconcellos, J. M. and Oliveira, N. G. *Ocean Engineering*, 2011, 38, (8–9), 967–975.

During the useful life of a vessel it undergoes various changes that lead to uncertainties in determining the displacement and centre of gravity. Besides upgrading work, the very operation of the platform itself involving constant ballast and oil loading and unloading or the use of maintenance equipment can generates uncertainties concerning the displacement and centre of gravity. These, therefore, are the parameters that present uncertainties inherent to the vessel's operations. Taking this into account, one example of the application of uncertainties on the displacement and transversal and vertical centre of gravity positions will be presented in the analysis of the static stability of a converted FPSO tanker. Another question raised in this work is the deterministic treatment of certain criteria for the parameters that depend on random factors, such as wind, currents and waves. This paper will present a probabilistic approach for the calculation of the roll angle according to resolution IMO A.562 (environment criteria). The two chosen criteria for this analysis were resolutions IMO A.167 (general criteria) and A.562 (weather criterion).

12/00624 Study of operational parameters improvement of natural-gas cogeneration plant in public buildings in Thailand

Somcharoenwattana, W. *et al. Energy and Buildings*, 2011, 43, (4), 925–934.

This paper presents two case studies of performance improvement alternatives. The first one is the 52.5 MWe cogeneration plant at the Suvarnabhumi airport, and the second is the 9.9 MWe cogeneration plant of the government office building complex. Both plants are located in Bangkok. Performance improvements assume changing system design and operational plans during on-peak and off-peak periods with applying chilled water storage for more flexible operation. Such analysis gives opportunity for improvement of plant efficiency, primary energy saving, emission reduction and economical benefits. In case study 1, the selection of new prime mover results in overall efficiency improvement from 48% to 61%, 24% increase of primary energy saving, and 27% improvement of CO_2 emission reduction. Significant amount of primary energy is saved 1451 TJ/year and CO_2

emission reduction is 129,271 tCO_2/year. The profit is increased to US$24.80 million/year and the payback period is 4.77 years. In case study 2, the application of chilled water storage leads to maximum profit of US$2.63 million/year. The results show that the selection of plant components should be made very carefully in the design stage, as well as that permanent control and optimization of plant operation in the exploitation phase is essential. Economic aspects of cogeneration plants are more sensitive to changeable input parameters than classical separate heat and power generation since cogeneration plants are more complex in the aspects of process configuration and products costs/values (electricity, steam, hot water, and chilled water). Having in mind the future development of the natural gas distribution network in Thailand, it can be estimated that the potential of power generation in public buildings is around 1.3 GWe. Comparing the Thailand total primary energy supply for commercial buildings, it means reduction of about 9.1%.

12/00625 Thermodynamic analysis on post-combustion CO_2 capture of natural-gas-fired power plant

Amrollahi, Z. *et al. International Journal of Greenhouse Gas Control*, 2011, 5, (3), 422–426.

A chemical absorption, post-combustion CO_2 capture unit is simulated and an exergy analysis has been conducted, including irreversibility calculations for all process units. By pinpointing major irreversibilities, new proposals for efficient energy integrated chemical absorption process are suggested. Further, a natural-gas combined-cycle power plant with a CO_2 capture unit has been analysed on an exergetic basis. By defining exergy balances and black-box models for plant units, investigation has been made to determine effect of each unit on the overall exergy efficiency. Simulation of the chemical absorption plant was done using UniSim Design software with Amines Property Package. For natural-gas combined-cycle design, GT PRO software (Thermoflow, Inc.) has been used. For exergy calculations, spreadsheets are created with Microsoft Excel by importing data from UniSim and GT PRO. Results show the exergy efficiency of 21.2% for the chemical absorption CO_2 capture unit and 67% for the CO_2 compression unit. The total exergy efficiency of CO_2 capture and compression unit is 31.6%.

12/00626 World oil and agricultural commodity prices: evidence from nonlinear causality

Nazlioglu, S. *Energy Policy*, 2011, 39, (5), 2935–2943.

The increasing co-movements between the world oil and agricultural commodity prices have renewed interest in determining price transmission from oil prices to those of agricultural commodities. This study extends the literature on the oil–agricultural commodity prices nexus, which particularly concentrates on non-linear causal relationships between the world oil and three key agricultural commodity prices (corn, soybeans, and wheat). To this end, the linear causality approach of Toda–Yamamoto and the non-parametric causality method of Diks–Panchenko are applied to the weekly data spanning from 1994 to 2010. The linear causality analysis indicates that the oil prices and the agricultural commodity prices do not influence each other, which supports evidence on the neutrality hypothesis. In contrast, the non-linear causality analysis shows that: (i) there are non-linear feedbacks between the oil and the agricultural prices, and (ii) there is a persistent unidirectional non-linear causality running from the oil prices to the corn and to the soybeans prices. The findings from the non-linear causality analysis therefore provide clues for better understanding the recent dynamics of the agricultural commodity prices and some policy implications for policy makers, farmers, and global investors. This study also suggests the directions for future studies.

Derived gaseous fuels

12/00627 Catalytic decomposition of methane and methane/CO_2 mixtures to produce synthesis gas and nanostructured carbonaceous material

Pinilla, J. L. *et al. Fuel*, 2011, 90, (6), 2245–2253.

Methane and CO_2 are the main components of biogas; therefore its direct conversion into a higher added value gas as syn-gas (mixture of CO and H_2) is a very interesting alternative for the valorization of such renewable resource. In this work, firstly a thermodynamic analysis of the decomposition of CH_4:CO_2 mixtures at different temperatures and CH_4:CO_2 ratios simulating the biogas composition, has been carried out. Secondly, the decomposition of a mixture with a molar ratio of 1:1 has been studied in a fixed-bed reactor by using a Ni/Al_2O_3 based catalyst, at the temperature range in which according to the thermodynamic study, carbon formation is favoured. Results obtained have been compared to those of methane decomposition carried out under the same experimental conditions. Co-feeding of CO_2 and CH_4 avoids catalyst deactivation substantially, allowing to obtain a syn-gas with H_2:CO ratio close to 1. Moreover, the carbon obtained from mixtures of CH_4 and CO_2 is deposited as fishbone carbon nanofibres at 600 °C and ribbon carbon nanofibres at 700 °C, both being materials with high added value which can be used in multiple applications.

12/00628 Char and char-supported nickel catalysts for secondary syngas cleanup and conditioning

Wang, D. *et al. Applied Energy*, 2011, 88, (5), 1656–1663.

Tars in biomass gasification systems need to be removed to avoid damaging and clogging downstream pipes or equipment. In this study, Ni-based catalysts were made by mechanically mixing NiO and char particles at various ratios. Catalytic performance of the Ni/char catalysts was studied and compared with performance of wood char and coal char without Ni for syngas cleanup in a laboratory-scale updraft biomass gasifier. Reforming parameters investigated were reaction temperature (650–850 °C), NiO loading (5–20% of the weight of char support), and gas residence time (0.1–1.2 s). The Ni/coalchar and Ni/woodchar catalysts removed more than 97% of tars in syngas at 800 °C reforming temperature, 15% NiO loading, and 0.3 s gas residence time. Analysis of syngas composition indicated that concentrations of H_2 and CO in syngas significantly. Furthermore, performance of the Ni/coalchar catalyst was continuously tested for 8 h. There was slight deactivation of the catalyst in the early stage of tar/syngas reforming; however, the catalyst was able to stabilize soon after. It was concluded that chars especially coal char can be an effective and inexpensive support of NiO for biomass gasification tar removal and syngas conditioning.

12/00629 Co-gasification of coal and wood in a dual fluidized bed gasifier

Aigner, I. *et al. Fuel*, 2011, 90, (7), 2404–2412.

In the last decade the reduction of CO_2 emissions from fossil fuels became a worldwide topic. Co-gasification of coal and wood provides an opportunity to combine the advantages of the well-researched usage of fossil fuels such as coal with CO_2-neutral biomass. Gasification itself is a technology with many advantages. The producer gas can be used in many ways; for electric power generation in a gas engine or gas turbine, for Fischer–Tropsch synthesis of liquid fuels and also for production of gaseous products such as synthetic natural gas (bio SNG). Moreover, the use of the producer gas in fuel cells is under investigation. The mixture of coal and wood leads to the opportunity to choose the gas composition as best befits the desired process. Within this study the focus of investigation was of gasification of coal and wood in various ratios and the resulting changes in producer gas composition. Co-gasification of coal and wood leads to linear producer gas composition changes with linear changing load ratios (coal/wood). Hydrogen concentrations rise with increasing coal ratio, while CO concentrations decrease. Due to the lower sulfur and nitrogen content of wood, levels of the impurities NH_3 and H_2S in the producer gas fall with decreasing coal ratio. It is also shown that the majority of sulfur is released in the gasification zone and, therefore, no further cleaning of the flue gas is necessary. All mixture ratios, from 100 energy% to 0 energy% coal, performed well in the 100 kW dual fluidized bed gasifier. Although the gasifier was originally designed for wood, an addition of coal as fuel in industrial sized plants based on the same technology should pose no problems.

12/00630 Comparison by the use of numerical simulation of a MCFC-IR and a MCFC-ER when used with syngas obtained by atmospheric pressure biomass gasification

Di Carlo, A. *et al. International Journal of Hydrogen Energy*, 2011, 36, (13), 7976–7984.

In order to realize biomass potential as a major source of energy in the power generation and transport sectors, there is a need for high efficient and clean energy conversion devices, especially in the low-medium range suiting the disperseness of this fuel. Large installations, based on boilers coupled to steam turbines (or IGCC), are too complex at smaller scale, where biomass gasifiers coupled to ICEs have low electrical efficiency (15–30%) and generally not negligible emissions. This paper analyses new plants configurations consisting of fast internal circulated fluidized-bed gasifiers, hot-gas conditioning and cleaning, high temperature fuel cells (MCFC), micro gas turbines, water gas shift reactor and PSA to improve flexibility and electric efficiency at medium scale. The power plant feasibility was analysed by means of a steady state simulation realized through the process simulator Chemcad in which a detailed 2D Fortran model has been integrated for the MCFC. A comparison of the new plant working with external (MCFC-ER) and internal (MCFC-IR) reforming MCFC was carried out. The small amount of methane in the syngas obtained by atmospheric pressure biomass gasification is not enough to exploit internal reforming cooling in the MCFC. This issue has been solved by the use of pre-reformer working as methanizer upstream the MCFC. The results of the simulations shown that, when MCFC-IR is used, the parameters of the cell are better managed. The result is a more

efficient use of fuel even if some energy has to be consumed in the methanizer. In the MCFC-IR and MCFC-ER configurations, the calculated cell efficiency is, respectively, 0.53 and 0.42; the electric power produced is, respectively, 236 and 216 kW_e, and the maximum temperature reached in the cell layer is, respectively, 670 and 700 °C. The MCFC-ER configuration uses a cathode flowrate for MCFC cooling that are 30% lower than MCFC-IR configuration. This reduces pressure drop in the MCFC, possible crossover effect and auxiliaries power consumption. The electrical efficiency for the MCFC-IR configuration reaches 38%.

12/00631 Effects of syngas type on the operation and performance of a gas turbine in integrated gasification combined cycle

Kim, Y. S. *et al. Energy Conversion and Management*, 2011, 52, (5), 2262–2271.

The authors investigated the effects of firing syngas in a gas turbine designed for natural gas. Four different syngases were evaluated as fuels for a gas turbine in the integrated gasification combined cycle (IGCC). A full off-design analysis of the gas turbine was performed. Without any restrictions on gas turbine operation, as the heating value of the syngas decreases, a greater net system power output and efficiency is possible due to the increased turbine mass flow. However, the gas turbine is more vulnerable to compressor surge and the blade metal becomes more overheated. These two problems can be mitigated by reductions in two parameters: the firing temperature and the nitrogen flow to the combustor. With the restrictions on surge margin and metal temperature, the net system performance decreases compared to the cases without restrictions, especially in the surge margin control range. The net power outputs of all syngas cases converge to a similar level as the degree of integration approaches zero. The difference in net power output between unrestricted and restricted operation increases as the fuel heating value decreases. The optimal integration degree, which shows the greatest net system power output and efficiency, increases with decreasing syngas heating value.

12/00632 Evaluation of carbon deposition behavior on the nickel/yttrium-stabilized zirconia anode-supported fuel cell fueled with simulated syngas

Chen, T. *et al. Journal of Power Sources*, 2011, 196, (5), 2461–2468.

The nickel/yttrium-stabilized zirconia (Ni/YSZ) anode-supported solid oxide fuel cells (SOFCs) have been operated under various simulated syngases at different temperatures to investigate the degradation behaviour of the cells caused by carbon deposition. The results show that the carbon morphology and the cell performance degradation are influenced significantly by the operation temperature. The stability of the cell fuelled with syngas can be improved by applying a constant current, but the cell degraded quickly after carbon deposition. The microstructure damage is close to the anode surface and leads to a conductivity decrease, which is an important reason for the cell degradation and failure at 750 °C. Conversely, the degradation behaviour at 650 °C is mainly due to solid carbon deposits inside of the anode that impede fuel diffusion and electrochemical reactions on the anodic side. The effect of carbon deposition on the microstructure degradation is also investigated using transmission electron microscope.

12/00633 Hydrogen/carbon monoxide syngas burning rates measurements in high-pressure quiescent and turbulent environment

Liu, C. C. *et al. International Journal of Hydrogen Energy*, 2011, 36, (14), 8595–8603.

A high-pressure, double-chamber, fan-stirred, large-scale explosion facility is proposed for measurements of laminar and turbulent burning velocities, S_L and S_T, of centrally-ignited hydrogen and carbon monoxide syngas/air mixtures over an initial pressure range of $p = 0.1$–1.0 MPa. Results show that lean syngas laminar flames at elevated pressure are highly unstable resulting in cellular structures all over the expanding flame front surface, where $S_L \sim p^{-0.15}$ having a relatively modest decrease with pressure as compared to lean methane flames where $S_L \sim p^{-0.50}$. Contrarily, as to lean syngas turbulent flames, values of S_T increase with increasing pressure ($S_T \sim p^{0.15}$) at a fixed r.m.s. turbulent fluctuating velocity ($u' \approx 1.4$ m/s). Moreover, it is also shown that increasing u'/S_L is still a way much more effective in increasing values of S_T/S_L than increasing pressure. Finally, discussions are offered and area for further studies identified.

12/00634 Hydrogen-rich gas production from waste plastics by pyrolysis and low-temperature steam reforming over a ruthenium catalyst

Namioka, T. *et al. Applied Energy*, 2011, 88, (6), 2019–2026.

Operating conditions for low-temperature pyrolysis and steam reforming of plastics over a ruthenium catalyst were investigated. In the range studied, the highest gas and lowest coke fractions for polystyrene (PS) with a 60 g h^{-1} scale, continuous-feed, two-stage gasifier were obtained with a pyrolyser temperature of 673 K, steam reforming temperature of 903 K, and weight hourly space velocity (WHSV) of 0.10 g-sample g-catalyst^{-1} h^{-1}. These operating conditions are consistent with optimum conditions reported previously for polypropylene. The results indicate that at around 903 K, the activity of the ruthenium catalyst was high enough to minimize the difference between the rates of the steam reforming reactions of the pyrolysates from polystyrene and polypropylene. The proposed system thus has the flexibility to compensate for differences in chemical structures of municipal waste plastics. In addition, the steam reforming temperature was about 200 K lower than the temperature used in a conventional Ni-catalysed process for the production of hydrogen. Low-temperature steam reforming allows for lower thermal input to the steam reformer, which results in an increase in thermal efficiency in the proposed process employing a Ru catalyst. Because low-temperature steam reforming can be also expected to reduce thermal degradation rates of the catalyst, the pyrolysis-steam reforming process with a Ru catalyst has the potential for use in small-scale production of hydrogen-rich gas from waste plastics that can be used for power generation.

12/00635 Influence of feed characteristics on the microwave-assisted pyrolysis used to produce syngas from biomass wastes

Fernández, Y. and Menéndez, J. A. *Journal of Analytical and Applied Pyrolysis*, 2011, 91, (2), 316–322.

A series of biomass wastes (sewage sludges, coffee hulls and glycerol) were subjected to pyrolysis experiments under conventional and microwave heating. The influence of the initial characteristics of the raw materials upon syngas production was studied. Glycerol yielded the highest concentration of syngas, but the lowest H_2/CO ratio, whereas sewage sludges produced the lowest syngas production with the highest H_2/CO molar ratio. Coffee hull displayed intermediate values for both parameters. Microwave heating produced greater gas yields with elevated syngas content than conventional pyrolysis. Moreover, microwave pyrolysis always achieved the desired effect with temperature increase upon the pyrolysis products, whatever biomass material was employed. This could be due to the hot spot phenomenon, which only occurs under microwave heating. In addition, a comparison of the energy consumption of the traditional and microwave-assisted pyrolysis is also presented. Results point at microwave system as less time and energy consuming in comparison to conventional system.

12/00636 Natural gas to synthesis gas – catalysts and catalytic processes

Aasberg-Petersen, K. *et al. Journal of Natural Gas Science and Engineering*, 2011, 3, (2), 423–459.

Natural gas is a dominating feedstock for the production of several bulk chemicals such as ammonia, methanol, and dimethyl ether (DME), and for the increasingly important production of synthetic liquid fuels by Fischer–Tropsch synthesis (FT synthesis) and similar processes. A major step in the conversion of natural gas to products is the production of synthesis gas with the desired composition – ranging from the 3:1 mixture of hydrogen and nitrogen used for production of ammonia to the 1:1 mixture of hydrogen and carbon monoxide preferred for production of DME. Catalysts and catalytic processes are important in the production of synthesis gas from natural gas. As an example, production of ammonia synthesis gas may in modern plants involve up to eight separate catalytic process steps. In the article, relevant catalytic technologies are reviewed with emphasis on the present status and possible future developments. The relevant technologies are: final feed gas purification; adiabatic prereforming; fired tubular reforming; heat exchange steam reforming; adiabatic, oxidative reforming, mainly autothermal reforming (ATR) and secondary reforming; other reforming technologies such as catalytic partial oxidation (CPO) and ceramic membrane reforming (CMR); conversion of carbon monoxide to carbon dioxide by the shift reaction; final purification of synthesis gas, mainly removal of nitrogen compounds and removal of carbon oxides by methanation. After the discussion of the individual catalysts and catalytic process steps, applications are illustrated by summary descriptions of complete process concepts for production of ammonia, methanol, and hydrocarbons by low temperature FT synthesis (GTL). In a final section, future trends in the area are briefly discussed.

12/00637 Oriented linear cutting fiber sintered felt as an innovative catalyst support for methanol steam reforming

Pan, M. *et al. International Journal of Hydrogen Energy*, 2011, 36, (12), 7066–7073.

A kind of oriented linear cutting fibre sintered felt as an innovative catalyst support for methanol steam reforming was proposed. Multiple long copper fibres fabricated by cutting method were arranged in parallel and then sintered together in a mould pressing equipment under the condition of high temperature and protective gas atmosphere. The characteristics of oriented linear cutting fibre sintered felt coated with Cu/Zn/Al/Zr catalyst for methanol steam reforming were

experimental investigated under different GHSVs and reaction temperatures. Results indicated that the structure of sintered felt was the key influencing factor for the reaction performances on the condition of low GHSV or reaction temperature whereas the structure of sintered felt showed little influences with high GHSV or reaction temperature. By the analysis of SEM image and ultrasonic vibration testing method, it was found that the coarse surface pattern of cutting fibre could effectively enhance the adhesion intensity between the catalyst and the copper fibres, as well as present relatively large specific surface area in the microchannels. And hence the oriented linear cutting fibre sintered felt present better performances of methanol steam reforming than the oriented linear copper wire sintered felt on the condition of low GHSV or reaction temperature.

12/00638 Tandem bed configuration for sorption-enhanced steam reforming of methane
Reijers, H. Th. J. *et al. International Journal of Greenhouse Gas Control*, 2011, 5, (3), 531–537.
The required properties of a CO_2 sorbent for sorption-enhanced steam–methane reforming (SESMR) are derived following a top-down approach. First the required CO_2 equilibrium pressure of the sorbent is derived from system restraints, then a suitable sorbent is searched for matching the required CO_2 pressure. The selected material, barium orthotitanate Ba_2TiO_4, has been characterized and tested on lab-scale. From this follows that the capacity and kinetics are poor compared with CaO, which has been investigated for SESMR. The best use of Ba_2TiO_4 is in combination with CaO, making use of the good properties of both: the high capacity and good kinetics of CaO, and the low CO_2 equilibrium pressure of Ba_2TiO_4 allowing high CH_4 conversion at relatively low steam-to-methane ratios (3–4).

LNG

12/00639 A novel cryogenic power cycle for LNG cold energy recovery
Liu, Y. and Guo, K. *Energy*, 2011, 36, (5), 2828–2833.
A novel cryogenic cycle by using a binary mixture as working fluids and combined with a vapour absorption process was proposed to improve the energy recovery efficiency of an LNG (liquefied natural gas) cold power generation. The cycle was simulated with seawater as the heat source and LNG as the heat sink, and the optimization of the power generated per unit LNG was performed. Tetrafluoromethane (CF_4) and propane (C_3H_8) were employed as the working fluids. The effects of the working fluid composition, the recirculation rate of the C_3H_8-rich solution and the turbine intermediate pressure were investigated. In the cryogenic absorber, the C_3H_8-rich liquid absorbs the CF_4-rich vapour so that the mixture exhausting from the turbine can be fully condensed at a reduced pressure. This reduction of turbine back pressure can considerably improve the cycle efficiency. The presented cycle was compared with the C_3H_8 ORC (organic Rankine cycle), to show such performance improvement. It is found that the novel cycle is considerably superior to the ORC. The efficiency is increased by 66.3% and the optimized LNG recovery temperature is around −60 °C.

12/00640 Available power generation cycles to be coupled with the liquid natural gas (LNG) vaporization process in a Spanish LNG terminal
Querol, E. *et al. Applied Energy*, 2011, 88, (7), 2382–2390.
The boil off gas in Spanish liquid natural gas terminals is managed using recondensers. The electricity consumed by these terminals is bought in the Spanish wholesale market. Several power generating options using current available equipment and assuring the availability of the current terminal process have been analysed thermoeconomically. A new combined cycle using a gas turbine and a pure NH_3 Rankine cycle coupled with the natural gas vaporization process has been chosen as the most advisable one to be installed, due to the lower thermoeconomic cost obtained as shown in a new graphical representation similar to the existing exergetic cost diagrams.

Hydrogen generation and storage

12/00641 Cycle behaviour of iron ores in the steam-iron process
Lorente, E. *et al. International Journal of Hydrogen Energy*, 2011, 36, (12), 7043–7050.
The use of several commercial iron ores usually employed as pigments, to store and supply pure hydrogen by means of the steam-iron process has been proposed and analysed. The process roughly consists of repeated series of alternate reduction and oxidation steps in which a reducing stream (H_2 + CO, or in general H_2 enriched fuels) reacts with the iron oxide rendering the metal or a partially reduced oxide. Pure hydrogen is released during the re-oxidation with steam. The studied iron ores contain some impurities that accounting minor percentages (<10 wt%) enhance the behaviour of the solid. This improvement regards not only to the reduction and oxidation rate, but especially to the ability of the solid to maintain a given redox capacity along cycles. Also concerning this topic, the effect of the presence of these natural additives has been investigated in order to determine the inert behaviour of methane as a potential reducing agent. This study allowed the determination of the maximum temperature at which carbon formation is inhibited so that the subsequent released hydrogen will not be contaminated by carbon compounds.

12/00642 Effect of platinum doping of activated carbon on hydrogen storage behaviors of metal-organic frameworks-5
Lee, S.-Y. and Park, S.-J. *International Journal of Hydrogen Energy*, 2011, 36, (14), 8381–8387.
Platinum doped on activated carbons/metal-organic frameworks-5 hybrid composites (Pt-ACs-MOF-5) was used to obtain a high hydrogen storage capacity. The surface functional groups and surface charges were confirmed by Fourier transfer infrared spectroscopy (FT-IR) and zeta-potential measurement, respectively. The microstructures were characterized by X-ray diffraction (XRD). The sizes and morphological structures were also evaluated using a scanning electron microscopy (SEM). The pore structure and specific surface area were analysed by N_2/77 K adsorption/desorption isotherms. The hydrogen storage capacity was studied by BEL-HP at 298 K and 100 bar. The results revealed that the hydrogen storage capacity of the Pt-ACs-MOF-5 was 2.3 wt% at 298 K and 100 bar, which is remarkably enhanced by a factor of above five times and above three times compared with raw ACs and MOF-5, respectively. In conclusion, it was confirmed that platinum particles played a major role in improving the hydrogen storage capacity; MOF-5 would be a significantly encouraging material for a hydrogen storage medium as a receptor.

12/00643 Evaluation of hydrogen production capabilities of a grid-assisted wind–H_2 system
Clúa, J. C. G. *et al. Applied Energy*, 2011, 88, (5), 1857–1863.
This paper analyses the operation of a grid-assisted wind power system dedicated to hydrogen production. Several operation modes are evaluated with the aim of establishing control strategies for different requirements such as optimum wind power capture, maximum H_2 production rate and maximum clean H_2 production. Each operation mode is achieved by specific control of the grid-side power electronic converter. The operation of the wind turbine, the electrolyser and the electronic converter connected to a common DC-bus are represented on the same voltage–current plane. Basic schemes of controllers are suggested to fulfill operation requirements. Curves of power and H_2 production rate as function of wind speed are displayed for each mode. Also, conclusions about contribution of wind energy to clean H_2 are drawn.

12/00644 Exergoenvironmental analysis of a steam methane reforming process for hydrogen production
Boyano, A. *et al. Energy*, 2011, 36, (4), 2202–2214.
Steam methane reforming (SMR) is one of the most promising processes for hydrogen production. Several studies have demonstrated its advantages from the economic viewpoint. Nowadays process development is based on technical and economical aspects; however, in the near future, the environmental impact will play a significant role in the design of such processes. In this paper, an SMR process is studied from the viewpoint of overall environmental impact, using an exergoenvironmental analysis. This analysis presents the combination of exergy analysis and life cycle assessment. Components where chemical reactions occur are the most important plant components from the exergoenvironmental point of view, because, in general, there is a high environmental impact associated with these components. This is mainly caused by the exergy destruction within the components, and this in turn is mainly due to the chemical reactions. The obtained results show that the largest potential for reducing the overall environmental impact is associated with the combustion reactor, the steam reformer, the hydrogen separation unit and the major heat exchangers. The environmental impact in these components can mainly be reduced by improving their exergetic efficiency. A sensitivity analysis for some important exergoenvironmental variables is also presented in the paper.

12/00645 Hydrogen generation by splitting water with Al–Ca alloy
Zhao, Z. *et al. Energy*, 2011, 36, (5), 2782–2787.

A new hydrogen generation material, Al–Ca alloy, is prepared by ball milling method. Results show the prepared Al–Ca alloy can react with to produce hydrogen, but its hydrogen yield is lower. NaCl addition can further greatly improve hydrogen generation of Al–Ca alloys. The amount of NaCl addition and ball milling time depends on the Ca contents of alloys. As the Ca contents of alloy increase, the amount of NaCl addition or ball milling time may be reduced accordingly. Increasing Ca contents, NaCl addition or ball milling time is beneficial to improve the hydrogen generation rate. Al–Ca alloys can react with water to produce hydrogen at the temperature ranging from 10 °C to 80 °C, and simultaneously a great amount of heat is released. With the increase of air exposure time, the dense Al_2O_3 and CaO layer formed on the surface of alloy particles will reduce the oxidation reaction rate. Chloride ions and sulfate ions can greatly decrease the induction period of hydrogen generation reaction and obviously improve hydrogen generation rate. Ca^{2+} ions and Mg^{2+} ions can affect the production of hydrogen due to their strong affinity to OH^-, especially Mg^{2+} ions which greatly decrease the hydrogen yield to 20%.

12/00646 Hydrogen production by catalysed pyrolysis of polymer blends

Bober, P. *et al. Fuel*, 2011, 90, (6), 2334–2339.

Differently composed mixtures of HDPE and PMMA were pyrolysed at 700 and 815 °C in pyrolysis reactor. It was directly coupled with gas chromatography/mass spectrometry (GC/MS). On line pyrolysis GC/MS was applied in analysis of hydrogen, methane and carbon monoxide yielding in polymer blends pyrolysate with/without metal (Ni, Co) coated particles, tested as a methane to hydrogen conversion catalysts supporting additives. They were prepared by electrochemical deposition of Ni and Co on the small iron particles surface. Maximum hydrogen production was confirmed at the highest pyrolysis temperature (815 °C), and the highest HDPE contents in the blends mixture. Higher content of the PMMA in the mixture led to higher production of CO and lower hydrogen contents in pyrolysate. Nickel and cobalt containing additives affected production of hydrogen and other components at both 700 and 815 °C pyrolysis temperatures. An effect of different heat distribution between metal particles and polyblends occurred and affected hydrogen production. Application of pyrolysis gas chromatography in hydrogen production from polyblends represents an important tool to model future technological outputs as well simultaneous hydrogen production and CO, CO_2 elimination. Moreover, catalysis assisted conversion of methane to hydrogen can improve final hydrogen content in pyrolysate. Effectivity of pyrolysis hydrogen production was determined by its quantification based on analytical calibration.

12/00647 Hydrogen production over Au-loaded mesoporous-assembled $SrTiO_3$ nanocrystal photocatalyst: effects of molecular structure and chemical properties of hole scavengers

Puangpetch, T. *et al. Energy Conversion and Management*, 2011, 52, (5), 2256–2261.

The hydrogen production via the photocatalytic water splitting under UV irradiation using different compounds as hole scavengers (including methanol, formic acid, acetic acid, propanoic acid, hydrochloric acid, and sulfuric acid) under a low concentration range (<8 vol.%) was investigated over the 1 wt% Au-loaded mesoporous-assembled $SrTiO_3$ nanocrystal photocatalyst. The results indicated that the hydrogen production efficiency greatly depended on the molecular structure, chemical properties, and concentration of the hole scavengers. Formic acid, which is the smallest and completely-dissociated water-soluble carboxylic acid, exhibited the highest hydrogen production enhancement ability. The 2.5 vol.% aqueous formic acid solution system provided the highest photocatalytic hydrogen production rate.

12/00648 Hydrogen production via urea electrolysis using a gel electrolyte

King, R. L. and Botte, G. G. *Journal of Power Sources*, 2011, 196, (5), 2773–2778.

A technology was demonstrated for the production of hydrogen and other valuable products (nitrogen and clean water) through the electrochemical oxidation of urea in alkaline media. In addition, this process remediates toxic nitrates and prevents gaseous ammonia emissions. Improvements to urea electrolysis were made through replacement of aqueous KOH electrolyte with a poly(acrylic acid) gel electrolyte. A small volume of poly(acrylic acid) gel electrolyte was used to accomplish the electrochemical oxidation of urea improving on the previous requirement for large amounts of aqueous potassium hydroxide. The effect of gel composition was investigated by varying polymer content and KOH concentrations within the polymer matrix in order to determine which is the most advantageous for the electrochemical oxidation of urea and production of hydrogen.

12/00649 Photoelectrochemical hydrogen production with concentrated natural seawater produced by membrane process

Oh, S. *et al. Solar Energy*, 2011, 85, (9), 2256–2263.

Water shortages are anticipated to occur all over the world and are likely to have a significant effect on the availability of water for processes such as photocatalysis and electrolysis, as well as for drinking and industrial water. To overcome this problem, it has been suggested that seawater could be used as an alternative resource for the various water industries, such as hydrogen production, industrial and drinking water. Seawater contains a large amount of dissolved ion components, thus allowing it to be utilized as an electrolyte in photoelectrochemical system for producing hydrogen. Especially, the concentrated shows higher salinity (total dissolved solids, TDS) than the general seawater fed to the membrane process, because the permeate has a lower salinity and the retentate is more concentrated than the original seawater. For these reasons, the hydrogen evolution rate was investigated in a photoelectrochemical system, including anodized tubular TiO_2 and platinum as the photoanode and cathode, an external bias (solar cell) and the use of various types of seawater prepared by the nanofiltration membrane process as the electrolyte in the photoelectrochemical system. The results showed that the rate of hydrogen evolution obtained using the relatively tight nanofiltration membrane, NF90, operated at 20 MPa in the photoelectrochemical system is about 270 μmol/cm^2 h, showing that the retentate with a higher TDS than the general TDS of seawater acts as a more effective seawater electrolyte for hydrogen production.

12/00650 Recent advances in production of hydrogen from biomass

Kirtay, E. *Energy Conversion and Management*, 2011, 52, (4), 1778–1789.

The aim of this paper is to highlight various processes for the conversion of biomass into hydrogen gas. Biomass energy has the potential to be 'modernized' worldwide, i.e. produced and used efficiently and cost competitively, generally in the more convenient forms of gases, liquids, or electricity. Biomass will play an important role in the future global energy infrastructure for the generation of power and heat, but also for the production of chemicals and fuels. Biomass and biomass-derived fuels are can be used to produce hydrogen sustainably. The methods available for the hydrogen production from biomass can be divided into two main categories: thermochemical and biological routes.

12/00651 Safety study of the coupling of a VHTR with a hydrogen production plant

Bertrand, F. *et al. Nuclear Engineering and Design*, 2011, 241, (7), 2580–2596.

The present paper deals with specific safety issues resulting from the coupling of a nuclear reactor (very high temperature reactor, VHTR) with a hydrogen production plant (HYPP). The first part is devoted to the safety approach, this takes into account the safety standards and rules dedicated to the nuclear facility as well as those dedicated to the process industry. This approach enabled two main families of events to be distinguished: the so-called internal events taking place in the coupling circuit (transients, breaks in pipes and in heat exchangers) and the external events able to threat the integrity of the various equipments (in particular the VHTR containment and emergency cooling system) that could result from accidents in the HYPP. By considering a hydrogen production by means of the iodine/sulfur (IS) process, the consequences of both families of events aforementioned have been assessed in order to provide an order of magnitude of the effects of the incidents and accidents and also in order to propose safety provisions to mitigate these effects when it is necessary. The study of transients induced by a failure of a part of the HYPP has shown the possibility to keep the part of the HYPP unaffected by the transient under operation by means of an adapted regulation set. Moreover, the time to react in case of transfer of corrosive products in the VHTR containment has been assessed as well as the thermo-hydraulic loading that would experience the coupling pipes in case of very fast uncoupling of the facilities aiming at avoiding an excessive pressurization of the VHTR containment. Regarding the external events, by applying a method used in the process industries, the bounding representative scenarios have been identified on the basis of their consequences but also on the basis of their occurrence frequency. The consequences of the selected bounding scenarios, calculated taking into the source-term, the atmospheric dispersion and the pressure and toxic effects induced respectively by a hydrogen unconfined vapour cloud explosion (UVCE) and a sulfur dioxide release have been assessed. The resulting safety distance of about 100 m for the UVCE is fairly acceptable in terms of performance (head loss and thermal loss) of the coupling system. However, the longer safety distance (about 1.5 km) calculated for a SO_2 release implies to foresee a long distance to settle the control room of the site or to foresee provisions able to stop very fast the SO_2 leak.

04 BY-PRODUCTS RELATED TO FUELS

12/00652 A comparative evaluation of minerals and trace elements in the ashes from lignite, coal refuse, and biomass fired power plants
Singh, S. *et al. International Journal of Coal Geology*, 2011, 87, (2), 112–120.
Coal being a limited source of energy, extraction of energy from other sources like lignite, coal-refuse, and biomass is being attempted worldwide. The minerals and inorganic elements present in fuel feeds pose different technological and environmental concerns. Lignite ash, refuse ash, and biomass ash collected from Indian power plants burning lignite, coal-refuse, and mustard stalk, respectively, were analysed for physico-chemical characteristics and trace elements. The lignite ash has high SiO_2, CaO, MgO, Al_2O_3, and SO_3; the refuse ash has high SiO_2 and Fe_2O_3, but low SO_3; the biomass ash has high SiO_2 (but low Al_2O_3), and high CaO, MgO, K_2O, Na_2O, SO_3, and P_2O_5. A substantial presence of chloride (2.1%) was observed in the biomass ash. Quartz is the most abundant mineral species. Other minerals are mullite, hematite, gehlenite, anhydrite, and calcite in the lignite ash; orthoclase in the refuse ash; albite, sanidine, gehlenite, anhydrite, and calcite in the biomass ash. Ashes with high concentrations (> 100 mg/kg) of trace elements are: lignite ash (V < La < Mn < Cr < Ni < Nd < Ba < Ce, Zn < Sr); refuse ash (Cr < Ce < V < Rb < Mn < Sr, Zn < Ba); biomass ash (Cu < Zn < Ba, Sr). Based on Earth crust normalization, Co, Ni, As, Se, Mo, Zn, Pb, U, and REEs (except Pr and Er) are enriched in the lignite ash; molybdenum, Zn, Cs, Pb, Th, U, La, Ce, and Lu in the refuse ash; and Mo, Zn, Sr, Cs, Pb, and Lu in the biomass ash. Elements As, Zn, Mo, Ni, Pb, Rb, Cr, V, Ba, Sr, and REEs are correlated with Al, indicating the possibilities of their association with aluminium silicates minerals. Similarly, barium, Cs, Th, and U are correlated with iron oxides; molybdenum and Sr may also be associated with sulfates and chlorides. Due to the alkaline nature of these ashes, the high concentrations of As and Se in the lignite ash; molybdenum in the biomass ash; and Se in the refuse ash may pose environmental concerns.

12/00653 Carbonization behavior of coal-tar pitch modified with lignin/silica hybrid and optical texture of resultant semi-cokes
Lin, Q. *et al. Journal of Analytical and Applied Pyrolysis*, 2011, 90, (1), 1–6.
Coal-tar pitch was modified with a lignin/silica hybrid (LSH) from rice husk, and carbonization behaviour of the pitch-LSH mixtures and optical texture of resultant semi-cokes were studied in this paper. The carbonization behaviour was characterized using TGA, FTIR, SEM and EDS. In addition, the optical texture of resultant semi-cokes was characterized by polarized-light microscopy. Results show that the LSH addition has great effect on the carbonization behaviour of the pitch-LSH mixtures and the optical texture of resultant semi-cokes. The pitch-LSH mixtures have better thermal stability than coal-tar pitch, as indicated by that the initial weight loss temperature and carbonization yield of the pitch-LSH mixtures increase with increasing LSH content. There are more condensed polynuclear structures with high aromaticity in the resultant semi-cokes with increasing pyrolysis temperature. However, the LSH addition deteriorates the optical texture of resultant semi-cokes varying from coarse-grained mosaics to fine-grained mosaics. Furthermore, there exist a great many silica particles with size of less than 3 μm uniformly distributed in the pyrolysis product of the pitch-LSH mixture.

12/00654 Physical, chemical and mineralogical characterisation of hydraulically disposed fine coal ash from SASOL synfuels
Mahlaba, J. S. *et al. Fuel*, 2011, 90, (7), 2491–2500.
Coal serves as the primary energy source in most parts of the world. It is a fact that coal combustion yields enormous quantities of fly ash some of which are either hydraulically placed or dry dumped. The current study attempts to provide a comprehensive characterization of a disused alkaline fine coal ash dam (FCAD) towards assessing environmental impact, rehabilitation and utilization potential. Fine coal ash refers to a combination of approximately 83% power station fly ash and 17% gasification and bottom ash fines (particles <250 μm) at SASOL synfuels. The hydration products found in weathered fine coal ash (WFCA) using X-ray diffraction (XRD) and differential scanning calorimetry (DSC) are analcime, calcite, C–S–H gel, ettringite, hydrated gehlenite (Strätlingite), magnetite, periclase, pyrrhotite and sillimanite. High resolution scanning electron microscope (SEM) results provide additional proof that hydration products are present in WFCA. No indication of appreciable leaching was given by X-ray fluorescence (XRF) results except calcium and silicon. Thus evidence exists that pollutants from saline brines are immobilized in WFCA and an insight of reaction kinetics was obtained. High content of amorphous phase and lack of alteration in some geotechnical properties suggest that WFCA can be reutilized with lime addition to increase alkalinity and activate pozzolanic reactions.

12/00655 The effects of leaching and floatation on the ash fusion temperatures of three selected lignites
Li, F.-h. *et al. Fuel*, 2011, 90, (7), 2377–2383.
Experiments have been conducted with Huolinhe (HLH), Xiaolongtan (XLT), and Ethiopian (ET) lignites to investigate the effects of washing with water, acid-leaching, and floatation on their ash fusion temperatures (AFTs). The results show that the AFTs of XLT and ET are elevated by washing with water and floatation, but the AFT of HLH is decreased. The AFTs of all three lignites are increased markedly by acid leaching. A decrease in the total basic composition in ash increases its AFT, and vice versa. Changes in the mineral contents of the coals after treatment contribute to the variations in their AFTs. After washing with water, the lower AFT of HLH is brought about by the increases in the amounts of cordierite and anhydrite, whereas the higher AFT of XLT is caused by the decreases in the amounts of anhydrite and calcite. For the floatation treatment, the decrease of AFT for HLH is due to the reduction in the amount of kaolinite, but the elevation of AFT for XLT or ET is caused by the decrease in the amount of pyrite and the reductions in the amounts of gypsum and xanthoxenite, respectively. For the acid-leaching treatment, a decrease in the amount of pyrite and an increase in the amount of kaolinite result in increases in AFTs for HLH and XLT. Increases in the amounts of kaolinite and cristobalite in FET (ET after floatation), WET (ET after washing with water), and AET (ET after acid-leaching) lead to corresponding increases in the AFTs.

05 NUCLEAR FUELS

Scientific, technical

12/00656 A Petri net design of FPGA-based controller for a class of nuclear I&C systems
Chen, C.-K. *et al. Nuclear Engineering and Design*, 2011, 241, (7), 2597–2603.
This study is concerned with a field-programmable gate array (FPGA)-based controller design for the lack of FPGA-based solutions in the nuclear industry. An efficient design procedure is proposed to achieve simpler and affordable verification and validation of system efforts by explicitly modelling the interactions among processes. In the present approach, both of state diagram concept and Petri nets are used to model the concurrent processes. An illustrative example of automatic seismic trip system is provided. Synthesis results demonstrate that the proposed design is feasible and easy to implement.

12/00657 An experimental analysis of subcooled leakage flow through slits from high pressure high temperature pipelines
Ghosh, S. *et al. International Journal of Pressure Vessels and Piping*, 2011, 88, (8–9), 281–289.
The work presented here is an experimental investigation of the critical flashing flow of initially subcooled water through circumferential slits in pipes. The study provides first hand information about the prediction of leak flow rates in piping and pressure vessels retaining high temperature and high pressure. The dedicated experimental facility loop simulates the thermal hydraulic condition of pressurized heavy water reactors (PHWR). The critical flow characteristics found for varying leakage cross sections at different stagnation pressure and different degree of subcooling has been demonstrated in this paper. A marked decrease in mass flux has been found as subcooling decreases for a fixed stagnation pressure. More observation has revealed that the tighter slits or openings with very short duct as small as 0.8 cm flow length have different flow behaviour than greater opening dimensions or with longer flow channels or that for nozzles. The critical flow has been seen to occur at higher pressure differentials along the flaws and prominent changes in the flow rate is reported to occur with varying dimensional parameters of the slit or cracks.

12/00658 Characterization of sodium flow over hexagonal fuel subassemblies
Partha Sarathy, U. *et al. International Communications in Heat and Mass Transfer*, 2011, 38, (7), 928–937.

Steady flow of liquid sodium over a bundle of heat generating hexagonal subassemblies has been investigated. The cross flow pressure drop and heat transfer are characterized using the general purpose CFD code STAR-CD. Analysis has been carried out for both laminar and turbulent regimes of interest to liquid metal fast reactors. Turbulence has been modelled using low Reynolds number (Re) k–ε model. The estimated pressure drop and heat transfer coefficients are compared against that of a straight parallel plate channel. It is seen that in the low Reynolds number range, the pressure drop for the hexagonal path is nearly equal to that of the parallel plate channel for the same length. However, in the high Reynolds number range, the pressure drop of the hexagonal path is much higher than that in the parallel plate channel, the ratio being 2 at $Re = 2000$ while it is 3.6 at $Re = 20{,}000$. Two competing factors, namely, (i) jet impingement/flow development effect and (ii) flow separation effect are found to influence the average Nusselt number (Nu). In the laminar regime, the latter effect dominates leading to a decrease of the Nusselt number with an increase in the Reynolds number. However, in the turbulent regime, the former effect dominates leading to an increase in the Nusselt number with Reynolds number. The Nusselt number in the hexagonal path is about twice that of the parallel plate channel due to under development of velocity/temperature profiles and the recirculation associated with the hexagonal path due to the changes in flow direction. Detailed correlations for both the pressure drop and the average Nusselt number have been proposed.

12/00659 Control-oriented automatic system for transport analysis (ASTRA)–Matlab integration for tokamaks

Sevillano, M. G. *et al. Energy*, 2011, 36, (5), 2812–2819.

The exponential growth in energy consumption has led to a renewed interest in the development of alternatives to fossil fuels. Between the unconventional resources that may help to meet this energy demand, nuclear fusion has arisen as a promising source, which has given way to an unprecedented interest in solving the different control problems existing in nuclear fusion reactors such as tokamaks. The aim of this manuscript is to show how one of the most popular codes used to simulate the performance of tokamaks, the automatic system for transport analysis (ASTRA) code, can be integrated into the Matlab–Simulink tool in order to make the development of suitable controllers for tokamaks easier and more comfortable. As a demonstrative case study to show the feasibility and the goodness of the proposed ASTRA–Matlab integration, a modified anti-windup proportional integral derivative (PID)-based controller for the loop voltage of a tokamak has been implemented. The integration achieved represents an original and innovative work in the tokamak control area and it provides new possibilities for the development and application of advanced control schemes to the standardized and widely extended ASTRA transport code for tokamaks.

12/00660 Gallium nitride Schottky betavoltaic nuclear batteries

Lu, M. *et al. Energy Conversion and Management*, 2011, 52, (4), 1955–1958.

Gallium nitride (GaN) Schottky betavoltaic nuclear batteries (GNBB) are demonstrated in this work for the first time. GaN films are grown on sapphire substrates by metalorganic chemical vapour deposition (MOCVD), and then GaN Schottky diodes are fabricated by normal micro-fabrication process. Nickel with mass number of 63 (^{63}Ni), which emits β particles, is loaded on the GaN Schottky diodes to achieve GNBB. X-ray diffraction (XRD) and photoluminescence (PL) are carried out to investigate the crystal quality for the GaN films as grown. Current–voltage (I–V) characteristics shows that the GaN Schottky diodes are not jet broken down at -200 V due to consummate fabrication processes, and the open circuit voltage of the GNBB is 0.1 V and the short circuit current density is 1.2 nA cm^{-2}. The limited performance of the GNBB is due to thin effective energy deposition layer, which is only 206 nm to absorb very small partial energy of the β particles because of the relatively high dislocation density and carrier concentration. However, the conversion efficiency of 0.32% and charge collection efficiency (CCE) of 29% for the GNBB have been obtained. Therefore, the output power of the GNBB are expected to greatly increase with growing high quality thick GaN films.

12/00661 Hydrogen-enhanced degradation and oxide effects in zirconium alloys for nuclear applications

Zieliński, A. and Sobieszczyk, S. *International Journal of Hydrogen Energy*, 2011, 36, (14), 8619–8629.

The zirconium alloys used in nuclear industry include mainly Zr–Sn and Zr–Nb alloys of different chemical composition, microstructure and susceptibility to both hydrogen degradation and oxidation. The hypothetic nuclear accidents can create a real danger to the Zr alloys and stability of parts made of these alloys, and especially such as loss of coolant accident (LOCA) and reactivity initiated accidents (RIA). The hydrogen degradation can manifest itself in an appearance of hydride phases resulting in a substantial loss of plasticity, an increase in ductile–brittle transition, sometimes in a decrease in mechanical strength. The oxidation can prevent the hydrogen entry but at high temperatures the cracking of the oxide layer can form the easy hydrogen diffusion channels. Based on a substantial number of tests made so far and well-known thermodynamic and kinetic parameters, the general microstructure-dependent and temperature-dependent degradation model considering both hydrogen and oxidation could be elaborated.

12/00662 In-cell maintenance by manipulator arm with 3D workspace information recreated by laser rangefinder

Kitamura, A. *et al. Nuclear Engineering and Design*, 2011, 241, (7), 2614–2623.

This study developed a remote control system for maintenance of in-cell type fuel fabrication equipment. The system display recreated three-dimensional information of the workspace from data obtained by laser rangefinder and conventional cameras. It has allowed a manipulator arm to operate remotely with several control modes. In order to evaluate the effectiveness and usefulness of developed system, the authors implemented remote handling experiments using mock up equipment. Performance was compared for remote operation conducted using several different display and operation modes. It was confirmed that the system is able to maintain in-cell fuel fabrication equipment in each display and operation mode. Times required to complete the remote operations were collected and compared in each mode. It was observed that integration of 3D information from the laser rangefinder reduced operation time and reinforced visual information during remote operation.

12/00663 Steam leak detection in advance reactors via acoustics method

Singh, R. K. and Rama Rao, A. *Nuclear Engineering and Design*, 2011, 241, (7), 2448–2454.

Prediction of LOCA (loss of coolant activity) plays very important role in safety of nuclear reactor. Coolant is responsible for heat transfer from fuel bundles. Loss of coolant is an accidental situation that requires an immediate shut down of the reactor. Fall in system pressure during LOCA is the trip parameter used for initiating automatic reactor shut down. However, in primary heat transport system operating in two phase regimes, detection of small break LOCA is not simple. Due to very slow leak rates, time for the fall of pressure is significantly slow. From reactor safety point of view, it is extremely important to find reliable and effective alternative for detecting slow pressure drop in case of small break LOCA. One such technique is the acoustic signal caused by LOCA in small breaks. In boiling water reactors whose primary heat transport is to be driven by natural circulation, small break LOCA detection is important. For prompt action on post small break LOCA, steam leak detection system is developed to detect any leak inside the reactor vault. The detection technique is reliable and plays a very important role in ensuring safety of the reactor. Methodology developed for steam leak detection is discussed in present paper. The methods to locate the leak is also developed and discussed in present paper which is based on analysis of the signal.

12/00664 Uncertainty analysis of system fragility for seismic safety evaluation of NPP

Kim, J. H. *et al. Nuclear Engineering and Design*, 2011, 241, (7), 2570–2579.

In this study, a seismic probabilistic safety assessment (SPSA) methodology considering the uncertainty of fragilities was studied. A system fragility curve is estimated by combining component fragilities expressed by two variance sources, inherent randomness and modelling uncertainty. The sampling based methods, Monte Carlo simulation (MCS) and Latin hypercube sampling (LHS), were used to quantify the uncertainties of the system fragility. The SPSA of an existing nuclear power plant (NPP) was performed to compare the two uncertainty analysis methods. Convergence of the uncertainty analysis for the system fragility was estimated by calculating high confidence low probability of failure (HCLPF) capacity. Alternate HCLPF capacity by composite standard deviation was also verified. The annual failure frequency of the NPP was estimated and the result was discussed with that from the other researches. As a result, the criteria of the uncertainty analysis and its effect was investigated.

Economics, policy, supplies, forecasts

12/00665 Development and validation of a CFD model predicting the backfill process of a nuclear waste gallery

Gopala, V. R. *et al. Nuclear Engineering and Design*, 2011, 241, (7), 2508–2518.

Nuclear waste material may be stored in underground tunnels long term. The example treated in this paper is based on the current Belgian disposal concept for high-level waste (HLW), in which the nuclear waste material is packed in concrete shielded packages, called supercontainers, which are inserted into these tunnels. After placement of the packages in the underground tunnels, the remaining voids between the packages and the tunnel lining is filled-up with a cement-based material called grout in order to encase the stored containers into the underground spacing. This encasement of the stored containers inside the tunnels is known as the backfill process. A good backfill process is necessary to stabilize the waste gallery against ground settlements. A numerical model to simulate the backfill process can help to improve and optimize the process by ensuring a homogeneous filling with no air voids and also optimization of the injection positions to achieve a homogeneous filling. The objective of the present work is to develop such a numerical code that can predict the backfill process well and validate the model against the available experiments and analytical solutions. In the present work the rheology of grout is modelled as a Bingham fluid which is implemented in OpenFOAM – a finite volume-based open source computational fluid dynamics (CFD) tool box. Volume of fluid method (VOF) is used to track the interface between grout and air. The CFD model is validated and tested in three steps. First, the numerical implementation of the Bingham model is verified against an analytical solution for a channel flow. Second, the capability of the model for the prediction of the flow of grout is tested by means of a comparison of the simulations with experimental results from two standard flowability tests for concrete: the V-funnel flow time and slump flow tests. As a third step, the CFD model is compared with experiments in a transparent Plexiglas experimental test setup performed at Delft University of Technology, to test the model under more practical and realistic conditions. This experimental setup is a 1:12.5 scaled version of the setup of the full-scale mock-up test for backfilling of a waste gallery with emplaced canisters used in the European sixth framework project ESDRED. Furthermore, the Plexiglas setup is used to study the influence of different backfill parameters. The CFD results for a channel flow shows good comparison against the analytical solution, demonstrating the correct implementation of the Bingham model in OpenFOAM. Also, the CFD results for the flowability tests show very good comparison with the experimental results, thereby ensuring a good prediction of the flow of grout. The simulations of the backfill process show good qualitative comparison with the plexiglas experiment. However, occurrence of segregation and also varying rheological properties of the grout in the Plexiglas experiment results in significant differences between the simulation and the experiment.

12/00666 Diverting indirect subsidies from the nuclear industry to the photovoltaic industry: energy and financial returns
Zelenika-Zovko, I. and Pearce, J. M. *Energy Policy*, 2011, 39, (5), 2626–2632.
Nuclear power and solar photovoltaic energy conversion often compete for policy support that governs economic viability. This paper compares current subsidization of the nuclear industry with providing equivalent support to manufacturing photovoltaic modules. Current US indirect nuclear insurance subsidies are reviewed and the power, energy and financial outcomes of this indirect subsidy are compared to equivalent amounts for indirect subsidies (loan guarantees) for photovoltaic manufacturing using a model that holds economic values constant for clarity. The preliminary analysis indicates that if only this one relatively ignored indirect subsidy for nuclear power was diverted to photovoltaic manufacturing, it would result in more installed power and more energy produced by mid-century. By 2110 cumulative electricity output of solar would provide an additional 48,600 TWh over nuclear worth $5.3 trillion. The results clearly show that not only does the indirect insurance liability subsidy play a significant factor for nuclear industry, but also how the transfer of such an indirect subsidy from the nuclear to photovoltaic industry would result in more energy over the life cycle of the technologies.

12/00667 Effects of technological learning and uranium price on nuclear cost: preliminary insights from a multiple factors learning curve and uranium market modeling
Kahouli, S. *Energy Economics*, 2011, 33, (5), 840–852.
This paper studies the effects of returns to scale, technological learning, i.e. learning-by-doing and learning-by-searching, and uranium price on the prospects of nuclear cost decrease. An extended learning curve specification, named multiple factors learning curve (MFLC), is used. In a first stage, a single MFLC is estimated. In a second stage, the MFLC under the framework of simultaneous system of equations is estimated, which takes into account the uranium supply and demand. This permits not only to enhance the reliability of the estimation by incorporating the uranium price formation mechanisms in the MFLC via the price variable, but also to give preliminary insights about uranium supply and demand behaviours and the associated effects on the nuclear expansion. Results point out that the nuclear cost has important prospects for decrease via capacity expansion, i.e. learning-by-doing effects. In contrast, they show that the learning-by-searching as well as the scale effects have a limited effect on the cost decrease prospects. Conversely, results also show that uranium price exerts a positive and significant effect on nuclear cost, implying that when the uranium price increases, the nuclear power generation cost decreases. Since uranium is characterized by important physical availability, and since it represents only a minor part in the total nuclear cost, the authors consider that in a context of increasing demand for nuclear energy the latter result can be explained by the fact that the positive learning effects on the cost of nuclear act in a way to dissipate the negative ones that an increase in uranium price may exert. Further, results give evidence of important inertia in the supply and demand sides as well as evidence of slow correlation between the uranium market and oil market which may limit the inter-fuels substitutability effects, that is, nuclear capacity expansion and associated learning-by-doing benefits.

12/00668 Prospects for nuclear energy
Ahearne, J. F. *Energy Economics*, 2011, 33, (4), 572–580.
Support for a growth in nuclear power has been seen in China and the USA. Obstacles to further growth include cost, concerns about links to proliferation of nuclear weapons, public attitudes, how to handle nuclear waste, and workforce shortages. More than 20 countries are considering building nuclear power plants. Among new designs being considered are pebble-bed reactors and small reactors. Continued growth will require addressing the obstacles and continued safe operation of plants worldwide.

12/00669 The pebble bed modular reactor: an obituary
Thomas, S. *Energy Policy*, 2011, 39, (5), 2431–2440.
The high temperature gas-cooled reactor (HTGR) has exerted a peculiar attraction over nuclear engineers. Despite many unsuccessful attempts over half a century to develop it as a commercial power reactor, there is still a strong belief among many nuclear advocates that a highly successful HTGR technology will emerge. The most recent attempt to commercialize an HTGR design, the pebble bed modular reactor (PBMR), was abandoned in 2010 after 12 years of effort and the expenditure of a large amount of South African public money. This article reviews this latest attempt to commercialize an HTGR design and attempts to identify which issues have led to its failure and what lessons can be learnt from this experience. It concludes that any further attempts to develop HTGRs using pebble bed technology should only be undertaken if there is a clear understanding of why earlier attempts have failed and a high level of confidence that earlier problems have been overcome. It argues that the PBMR project has exposed serious weaknesses in accountability mechanisms for the expenditure of South African public money.

06 ELECTRICAL POWER SUPPLY AND UTILIZATION

Scientific, technical

12/00670 A high-flexibility DC load for fuel cell and solar arrays power sources based on DC–DC converters
Durán, E. *et al. Applied Energy*, 2011, 88, (5), 1690–1702.
In this paper, a flexible DC load to test and evaluate current–voltage characteristics of fuel cells stacks and photovoltaic modules based on DC–DC converters is proposed. The load features are simple structure, scalability, low cost, and its possibility to emulate an arbitrary load profile. The measure of the desired characteristics of fuel cells and photovoltaic modules further includes high speed of response and high fidelity. A comparison between conventional methods and the proposed one is also provided. Experimental results show the usefulness of the DC load proposed.

12/00671 A novel differential evolution application to short-term electrical power generation scheduling
Uyar, A. Ş. *et al. International Journal of Electrical Power & Energy Systems*, 2011, 33, (6), 1236–1242.

This paper proposes a new way of applying a differential evolution algorithm to short-term electrical power generation scheduling. Traditionally, the problem is divided into two subproblems. An evolutionary algorithm, which works with binary decision variables, is applied to the first subproblem to find a low cost scheduling of power generators, satisfying some operational constraints. Then, the lambda-iteration method, is used to calculate the power generated by the online generators. In this study, the problem is treated as a whole for the first time in literature and an application of a real-valued differential evolution algorithm is proposed. This approach eliminates the use of an iterative local search technique such as lambda-iteration in all solution evaluations. Through comparisons with results from literature, it is shown that the proposed method achieves a similar solution quality to existing methods, without needing the time-consuming lambda-iteration step. Finally, the new approach is applied to real-world data from the Turkish interconnected power network.

12/00672 A novel hybrid particle swarm optimization for economic dispatch with valve-point loading effects

Niknam, T. *et al. Energy Conversion and Management*, 2011, 52, (4), 1800–1809.

Economic dispatch (ED) is one of the important problems in the operation and management of the electric power systems which is formulated as an optimization problem. Modern heuristics stochastic optimization techniques appear to be efficient in solving ED problem without any restriction because of their ability to seek the global optimal solution. One of modern heuristic algorithms is particle swarm optimization (PSO). In PSO algorithm, particles change place to get close to the best position and find the global minimum point. Also, differential evolution (DE) is a robust statistical method for solving non-linear and non-convex optimization problem. The fast convergence of DE degrades its performance and reduces its search capability that leads to a higher probability towards obtaining a local optimum. In order to overcome this drawback a hybrid method is presented to solve the ED problem with valve-point loading effect by integrating the variable DE with the fuzzy adaptive PSO called FAPSO–VDE. DE is the main optimizer and the PSO is used to maintain the population diversity and prevent leading to misleading local optima for every improvement in the solution of the DE run. The parameters of proposed hybrid algorithm such as inertia weight, mutation and crossover factors are adaptively adjusted. The feasibility and effectiveness of the proposed hybrid algorithm is demonstrated for two case studies and results are compared with those of other methods. It is shown that FAPSO–VDE has high quality solution, superior convergence characteristics and shorter computation time.

12/00673 A ZigBee-based monitoring and protection system for building electrical safety

Huang, L.-C. *et al. Energy and Buildings*, 2011, 43, (6), 1418–1426.

In this paper, a ZigBee monitoring and protection system for building electrical safety is proposed. The main components of traditional distribution systems in buildings are no-fuse breakers (NFBs) and electrical outlets, whose functions are power transmission and overload protection respectively. NFBs only have the function of overload protection and are not completely effective in preventing electrical fires caused by poor contact or dust contamination. In addition, all equipments are disconnected in the same branch circuit due to NFB trips, thus the security and intelligence of the traditional distribution systems still need improvement. In this paper, the proposed system was constructed with protection mechanisms in order to enhance the functions of traditional distribution systems. The system can dynamically set the overload limit of outlets and avoid the effects on other equipment in the same branch circuit when the outlet disconnects the power. In addition, a self-protection function with temperature control was built in the outlet for fire prevention. This paper provides a detailed description of the proposed system, from design to implementation, as well as the results of the demonstration experiment.

12/00674 Advances and challenges in the development of power-generation systems at small scales

Walther, D. C. and Ahn, J. *Progress in Energy and Combustion Science*, 2011, 37, (5), 583–610.

The miniaturization of electro-mechanical devices, and the resulting need for micro-power generation (milliwatts to watts) with low weight, long life devices, has lead to the recent development of the field of micro-scale combustion and power generation. The primary objective of this new field is to leverage the high energy density of fuels, specifically liquid hydrocarbon fuels relative to batteries and all other energy storage devices other than nuclear fission, fusion or decay. As such, a miniaturized device even with a moderately efficient conversion of hydrocarbon fuels to power would result in increased lifetime and/or reduced weight of an electronic or mechanical system that are currently most often powered by electrochemical cells. Furthermore, improvements in this field may make possible novel applications and/or capability. In addition to the interest in miniaturization, the field is also driven by the potential fabrication of the devices using micro-electro-mechanical systems (MEMS) or rapid prototyping techniques, with their favourable characteristics for mass production and/or low unit cost. The micro-power generation field is very young, and still is in most cases in the feasibility stage. However, considering that it is a new frontier of technological development, and that only a few projects have been funded, it can be said that significant progress has been made to date. Currently there is consensus, at least among those working in the field, that combustion at the micro-scale is possible with proper thermal and chemical management. Several meso-scale and micro-scale combustors have been developed that appear to operate with good combustion efficiency. Some of these combustors have been applied to energize thermoelectric systems to produce power, although with low overall efficiency. Several turbines/engines have also been, or are being, developed, some of them currently producing positive power, albeit with low efficiency. Micro-rockets using solid or liquid fuels have been built and shown to produce thrust. More detailed scaling/modelling efforts are required to improve existing designs. Improvements in diagnostic, control and computational tools are expected to have a significant impact on the development of the field. Some brief scaling arguments are given in this work, and more detailed efforts are referred. A brief introduction to several of the fabrication techniques is presented in this work. Hydrogen-based and some preliminary specialty fuel micro-fuel cells have been successfully developed, and there is a need to develop reliable reformers (or direct conversion fuel cells) for liquid hydrocarbons so that the fuel cells become competitive with the batteries. In this work, the technological issues related to micro-scale combustion and the development of thermochemical devices for power generation will be discussed. Some of the systems currently being developed will be presented, on-going critical research issues under investigation, and other potential areas of development discussed. Comments regarding the opportunities and limitations of each of the techniques are also presented where applicable.

12/00675 All year power supply with off-grid photovoltaic system and clean seasonal power storage

Brinkhaus, M. *et al. Solar Energy*, 2011, 85, (10), 2488–2496.

The objective of the project is an all-year secure supply of alternating current based on a solar energy island grid consisting of serial components and seasonal energy storage. Photovoltaic modules, inverters, electrolysers, batteries, hydrogen stores and fuel cells form the basis of the independent power supply system. For this, selected load profiles were analysed and evaluated in theory and practice. The analysis is based on the results of the test runs of the system and the simulations, in which the combined hydrogen-battery-system is compared to the battery system. It was revealed that it is sensible to complement an island grid operating on lead batteries for short-term energy supply with hydrogen as a long-term store. This ensures a year-round supply security based on solar energy and the extension of the life span of the batteries required for hydrogen-based power stores. The systems based purely on batteries cannot provide perfect supply security during long periods of low solar radiation since they do not possess energy stores which allow long-term energy storage. Hence a seasonal energy store, such as hydrogen, is required to guarantee reliable power supply for every day of the year. Autonomous power supply systems with long-term energy stores operate independently from the public grid system and can be implemented without elaborate intelligent energy management. For this, however, the costs of the serial components must be reduced and the efficiency of the system must be improved.

12/00676 Bottoming cycles for electric energy generation: parametric investigation of available and innovative solutions for the exploitation of low and medium temperature heat sources

Bianchi, M. and De Pascale, A. *Applied Energy*, 2011, 88, (5), 1500–1509.

Many industrial processes and conventional fossil fuel energy production systems used in small-medium industries, such as internal combustion engines and gas turbines, provide low or medium temperature (i.e. 200–500 °C) heat fluxes as a by-product, which are typically wasted in the environment. The possibility of exploiting this wasted heat, converting it into electric energy by means of different energy systems, is investigated in this article, by extending the usual range of operation of existing technologies or introducing novel concepts. In particular, among the small size bottoming cycle technologies, the identified solutions which could allow to improve the energy saving performance of an existing plant by generating a certain amount of electric energy are: the organic Rankine cycle, the Stirling engine and the inverted Brayton cycle; this last is an original thermodynamic concept included in the performed comparative analysis. Moreover, this paper provides a parametric investigation of the thermodynamic performance of the different systems; in particular, for the inverted Brayton cycle, the effects of the heat source

characteristics and of the cycle design parameters on the achievable efficiency and specific power are shown. Furthermore, a comparison with other existing energy recovery solutions is performed, in order to assess the market potential. The analysis shows that the highest electric efficiency values, more than 20% with reference to the input heat content, are obtained with the organic Rankine cycle, while not negligible values of efficiency (up to 10%) are achievable with the inverted Brayton cycle, if the available temperature is higher than 400 °C.

12/00677 Chemical looping combustion for power generation – concept study for a 10 MW_{th} demonstration plant

Marx, K. *et al. International Journal of Greenhouse Gas Control*, 2011, 5, (5), 1199–1205.

A semi-commercial 10 MW_{th} chemical looping combustion (CLC) plant for power production is proposed as a next scale demonstration plant after successful operation of a 120 kW CLC pilot rig. The design criteria for the CLC boiler are derived from the experience obtained from the CLC pilot rig at Vienna University of Technology. The IPSEpro simulation environment is chosen for implementation of the process flow sheet of the CLC power plant. A single pressure steam cycle is suggested for this small-scale demonstration plant. Heat exchangers and a five-stage steam turbine are arranged. Basic design parameters of the power plant are derived from detailed mass and energy investigations and discussed. It turns out that the net electric efficiency of such a small scale plant can be expected to be in the range of 32.5–35.8%. However, a demonstration of CLC at such a scale is necessary in order to gain confidence in more sophisticated CLC power generation concepts at larger scale.

12/00678 Combustion optimization of a port-array inverse diffusion flame jet

Dong, L. L. *et al. Energy*, 2011, 36, (5), 2834–2846.

This paper is an experimental study on the combustion optimization of an innovative inverse diffusion flame (IDF) characterized by a central air jet surrounded by an array of fuel jets for impingement heating. An extensive investigation has been performed to explore the effects of the diameter ratio between air port and fuel port (d_{air}/d_{fuel}) on the IDF structure, particularly on its thermal and emission characteristics. Small, moderate and large d_{air}/d_{fuel} are investigated. It is found that under the same air flow rate (Q_{air} and d_{fuel}, d_{air} exerts a significant influence on the behaviour of the IDF by changing air/fuel hydrodynamics including air/fuel mixing intensity and air entrainment intensity. The experimental results show that smaller d_{air} produces a blue flame with better thermal characteristics, with higher maximum flame temperature ($T_{f,max}$), wider range of air jet Reynolds number (Re_{air}) for flame stability, and wider operation range of the overall equivalence ratio, ϕ. On the emission side, smaller d_{air} is found to produce more incomplete combustion products of CO and HC but less NO_x, which is attributed to lower volume of high-temperature zone and shorter flame residence time. The current investigation provides a valuable input for combustion and design optimization of this innovative IDF burner for impingement heating.

12/00679 Cycles in deregulated electricity markets: empirical evidence from two decades

Arango, S. and Larsen, E. *Energy Policy*, 2011, 39, (5), 2457–2466.

This study considers the 'cycle hypothesis' in electricity generation, which states that the introduction of deregulation in an electricity system might lead to sustained fluctuations of over- and under-capacity. The occurrence of cycles is one of the major threats for electricity markets as it affects the security of supply, and creates uncertainty in both the profitability of electricity companies and in consumer prices. The authors discuss the background for these cycles using analogies with other capital-intensive industries, along with evidence from the analysis of behavioural simulation models as well as from experimental electricity markets. Using data from the oldest deregulated markets, support is found for the hypothesis in the case of the English and Chilean markets, based on an autocorrelation analysis. Evidence from the Nordpool market is more ambiguous, although it may be that the first half of a cycle in generation capacity is observed. Comparing a simulation of the English market performed in 1992 with the actual performance the qualitative behaviour of the model is consistent with the actual evolution. Finally, possible mechanisms for damping cycles in electricity generation, such as mothballing, capacity payments, and reliability markets, are discussed.

12/00680 Desiccant wheel regenerated by thermal energy from a microcogenerator: experimental assessment of the performances

Angrisani, G. *et al. Applied Energy*, 2011, 88, (4), 1354–1365.

Hybrid desiccant HVAC systems have shown several advantages, compared to conventional cooling and dehumidification systems. Therefore, their use is also spreading for tertiary and residential buildings, especially when the regeneration of the desiccant can be obtained by using available waste heat. In this paper, an experimental analysis is presented on the performances of a silica-gel desiccant wheel, inserted in a test facility characterized by an advanced desiccant air handling unit, coupled to an electric chiller, a natural gas-fired boiler and a small scale cogenerator. The desiccant wheel is regenerated by using low temperature thermal energy recovered from the microcogenerator. The effects of the main thermal-hygrometric parameters (outdoor air humidity ratio and temperature, regeneration air temperature) on the desiccant wheel performances have been experimentally evaluated; in particular, the thermal-hygrometric properties of the process air exiting the rotor and the desiccant wheel effectiveness values have been obtained. Finally, fixing the regeneration temperature at its maximum available value (65 °C), ventilation and internal latent loads that the desiccant wheel can handle have been evaluated and compared to the required values, both for a set of cities all over the world and as a function of the thermal-hygrometric outdoor conditions.

12/00681 Determining optimal electricity technology mix with high level of wind power penetration

De Jonghe, C. *et al. Applied Energy*, 2011, 88, (6), 2231–2238.

Notwithstanding its variability and limited controllability, wind power is expected to contribute strongly to electricity generation from renewable energy sources in the coming decades. Treating wind power as non-dispatchable by subtracting its output from the original load profile, results in a net load profile, which must be covered by conventional power generation. The screening curve methodology is a first approximation to find the optimal generation technology mix, based on relative cost levels. However, increased variability of the net load profile, due to wind power generation, strongly influences system operation. Therefore a static linear programming investment model is developed to determine the optimal technology mix. This alternative methodology shows a reduced capacity of inflexible generation after including operational constraints to properly account for net load variability. In order to illustrate this methodology, an example is set up, showing the sensitivity with respect to ramp rates of conventional generation, transmission interconnection and energy storage. The comparison of those different sources of system flexibility suggests that energy storage facilities better facilitate the integration of wind power generation.

12/00682 Effect of load models on assessment of energy losses in distributed generation planning

Qian, K. *et al. International Journal of Electrical Power & Energy Systems*, 2011, 33, (6), 1243–1250.

Distributed generation (DG) is gaining in significance due to the keen public awareness of the environmental impacts of electric power generation and significant advances in several generation technologies which are much more environmentally friendly (wind power generation, micro-turbines, fuel cells, and photovoltaic) than conventional coal-, oil- and gas-fired plants. Accurate assessment of energy losses when DG is connected is gaining in significance due to the developments in the electricity market place, such as increasing competition, real time pricing and spot pricing. However, inappropriate modelling can give rise to misleading results. This paper presents an investigation into the effect of load models on the predicted energy losses in DG planning. Following a brief introduction the paper proposes a detailed voltage dependent load model, for DG planning use, which considers three categories of loads: residential, industrial and commercial. The paper proposes a methodology to study the effect of load models on the assessment of energy losses based on time series simulations to take into account both the variations of renewable generation and load demand. A comparative study of energy losses between the use of a traditional constant load model and the voltage dependent load model and at various load levels is carried out using a 38-node example power system. Simulations presented in the paper indicate that the load model to be adopted can significantly affect the results of DG planning.

12/00683 Enhancement of the current quality using efficient extraction and mitigation processes

Elnady, A. *et al. International Journal of Electrical Power & Energy Systems*, 2011, 33, (5), 1118–1124.

This paper introduces an innovative compensation strategy to extract and mitigate different current disturbances such as the current harmonics, cyclic current fluctuation and random current fluctuation. The contribution in this paper is that it does not need any mathematical model to represent the current disturbances and consequently extract these disturbances like the other common and utilized techniques. The proposed technique is simple for formulation and practical for implementation compared to the state-estimation techniques used for the same applications. The proposed strategy depends on recursive formulation of the Wiener filter. The presented

ideas in this paper are proved by digital simulation results using MATLAB/SIMULINK on the aforementioned current problems in the distribution systems.

12/00684 Exergy modeling of a new solar driven trigeneration system

Al-Sulaiman, F. A. *et al. Solar Energy*, 2011, 85, (9), 2228–2243.

In this paper, exergy modelling is used to assess the exergetic performance of a novel trigeneration system using parabolic trough solar collectors (PTSC) and an organic Rankine cycle (ORC). Four cases are considered: electrical-power, cooling-cogeneration, heating-cogeneration, and trigeneration. In this trigeneration system a single-effect absorption chiller is utilized to provide the necessary cooling energy and a heat exchanger is utilized to provide the necessary heating energy. The trigeneration system considered is examined using three modes of operation. They are: solar mode during the low-solar radiation time of the day, solar and storage mode during the high-solar radiation time of the day, and storage mode during night time. The storage mode is operated through the heat collected in a thermal storage tank during the solar and storage mode. The exergy efficiencies and exergy destruction rates are examined under the variation of the ORC evaporator pinch point temperature, ORC pump inlet temperature, and turbine inlet pressure. This study reveals that the maximum electrical-exergy efficiency for the solar mode is 7%, for the solar and storage mode is 3.5%, and for the storage mode is 3%. Alternatively, when trigeneration is used, the exergy efficiency increases noticeably. The maximum trigeneration-exergy efficiency for the solar mode is 20%, for solar and storage mode is 8%, and for the storage mode is 7%. Moreover, this study shows that the main sources of exergy destruction rate are the solar collectors and ORC evaporators. Therefore, careful selection and design of these two components are essential to reduce the exergy destructed by them and, thus, increase the exergy efficiencies of the system.

12/00685 Experimental analysis of microcogenerators based on different prime movers

Roselli, C. *et al. Energy and Buildings*, 2011, 43, (4), 796–804.

An experimental analysis performed by authors and other researchers on different micro combined heat and power (MCHP) units, based on reciprocating internal combustion (RIC) and Stirling engines, is reported in this paper. The most important energy, economic and environmental impact performance indices have been evaluated and compared using the same parameters with conventional systems for the separate production of heat and electricity with respect to Italy and Germany. The results obtained are encouraging. In fact the micro-cogeneration already allows primary energy savings of up to 27% (Italy) and 36% (Germany) and a pollutant emissions reduction of up to 35% (Germany) and 33% (Italy). The MCHPs perform better, in terms of primary energy savings and avoided equivalent CO_2 emissions, than the best available technology for almost all the units. As regards the economic analysis, it is evident that the greatest obstacle to wider use of small-scale cogeneration is its investment cost in comparison to similar technologies developed for larger sizes. Cogeneration does represent a mature technology even in small size applications. MCHP units based on reciprocating internal combustion engine are at the moment available on the market, although MCHPs based on Stirling engines are not widely used. However, thanks to the advantages that characterize this technology, there is an increasing interest in its use for residential and light commercial applications. In EU countries (UK, Germany and Italy), Japan and the USA, economic actions to support this technology are encouraging wider use of MCHP units.

12/00686 Generation allocation problem using a Hopfield-bisection approach including transmission losses

Benhamida, F. *et al. International Journal of Electrical Power & Energy Systems*, 2011, 33, (5), 1165–1171.

The objective of the paper is to solve generation allocation problem by minimizing total production cost, including transmission losses using a Hopfield neural network (HNN) algorithm. The generation allocation problem is commonly known as economic dispatch (ED). The computation procedure of the proposed HNN method is direct and do not need training and has been developed and mapped to solve the generation allocation problem of thermal generators. The procedure employs a linear input–output model for the neurons instead of the sigmoidal function. Formulations for solving the ED problem are explored. Through the application of these formulations, direct computation instead of iterations for solving the problem becomes possible. Not like the usual Hopfield methods, which select the weighting factors of the energy function by trials, the proposed method determines the corresponding factors by calculations. To include transmission losses in ED solution, the authors propose a dichotomy solution combined to the HNN. The effectiveness of the developed method is identified through its application to the 15-unit system. Computational results manifest that the method has a lot of excellent performances.

12/00687 Location of faults in power distribution laterals using superimposed components and programmable logic controllers

Aslan, Y. and Türe, Ş. *International Journal of Electrical Power & Energy Systems*, 2011, 33, (4), 1003–1011.

In this study, a digital fault location and monitoring technique using programmable logic controller (PLC) for primary overhead power distribution networks is presented. This technique employs pre- and post-fault current and voltage information along with data from the laterals. By using lateral current data transferred through shielded coaxial cables to the substation, the possibility of multiple fault point locations are eliminated. The effectiveness of this method is verified through electromagnetic transients program simulations.

12/00688 Productivity growth and biased technological change in hydroelectric dams

Briec, W. *et al. Energy Economics*, 2011, 33, (5), 853–858.

This paper analyses productivity growth and the nature of technical change in a sample of Portuguese hydroelectric generating plants over the period from 2001 to 2008. In a first step, the Luenberger productivity indicator is employed to estimate and decompose productivity change. A Malmquist productivity index is also used for a comparative purpose. The results paint a picture of mixed productivity performance in the Portuguese energy sector. The first decomposition underlines that, on average, the productivity variation is explained by the technological change. Then, in a second step, the authors analyse the nature of this technical change by using the recent concept of parallel neutrality. A global shift in the best practice frontier is observed as well as in the evidence of input bias in technical change.

12/00689 Testing for cross-subsidisation in the combined heat and power generation sector: a comparison of three tests

Amundsen, E. S. *et al. Energy Economics*, 2011, 33, (5), 750–757.

This paper examines cross-subsidization among combined heat and power producers in Denmark. Information on stand-alone costs for heat generation allows us to empirically compare the Faulhaber tests, tests with an upper bound on stand-alone costs (the Palmer tests) and the fully distributed cost test (FDC). All tests indicate a substantial amount of cross-subsidization from heat generation to power generation. It is shown that the FDC test is closer to that of the Faulhaber tests in its results than the Palmer tests. Thus as the Faulhaber tests are considered in the literature to be the theoretically correct tests, the FDC test is shown to be the best approximation for tests of cross-subsidization for this specific sector.

12/00690 Three-phase unbalance of distribution systems: complementary analysis and experimental case study

Bina, M. T. and Kashefi, A. *International Journal of Electrical Power & Energy Systems*, 2011, 33, (4), 817–826.

Three-phase unbalance is a familiar issue for power system researchers and engineers. This can introduce additional power losses in distribution network in steady states due to both negative and zero sequence components. It could also limit the loading capability of distribution transformers, well below their nominal ratings. There are many voltage and current unbalance definitions (e.g. IEEE and NEMA) for three-phase three-wire systems, assuming zero sequence currents to be of negligible practical value, for they cannot flow in three-wire systems. However, the zero sequence unbalance has significant current magnitude in three-phase with four-wire distribution networks, particularly in developing countries. Hence, this paper concentrates on the distribution unbalance, completing the available definitions in order to maintain tangible relationships between the level of unbalance and the cited consequences in distribution networks. Furthermore, practical works were performed on 11 selected 20 kV/0.4 kV substations within Tehran North-West Distribution System (TNWDS), where data loggers have been installed for 7 days to measure and record operating conditions of substations. Then, detailed analysis and assessment are suggested on empirical data to substantiate the presented complementary definitions and relationships.

Economics, policy, supplies, forecasts

12/00691 A database system for power systems customers and energy efficiency programs

Tsekouras, G. J. *et al. International Journal of Electrical Power & Energy Systems*, 2011, 33, (6), 1220–1228.

In this paper the design and development of a database for the registration of power utilities' customers and their energy behaviour are described. The database also includes the customers' devices and buildings, their demand curves, their tariffs, their connection with

power and gas networks, as well as the measures of demand side management and energy saving, which can be implemented. The main purpose of this database is to support end-use models and load forecasting algorithms for individual customers or their respective clusters, to study the effects of energy efficiency programs and to evaluate the last ones financially. It can be a useful tool for retailers, distribution electricity companies or regulatory authorities of energy.

12/00692 A demand response based solution for LMP management in power markets

Aazami, R. *et al. International Journal of Electrical Power & Energy Systems*, 2011, 33, (5), 1125–1132.

In recent years, most of the countries around the world have gone through the power system restructuring process. Along with this restructuring in power market there are some issues like local marginal pricing (LMP) problems that need to be solved base on demand response. In this article, demand-side management (DSM) programs have been effective to address LMPs in the market and system operators experience throughout their day-to-day activities. In particularly, these programs can help independent system operator (ISO) to reduce price volatility during peak demand hours. For achieving this purpose, a multi-objective optimal power flow is proposed to study the impact of a model for a demand response program on price spikes. Actually a new framework using demand response program was presented for price spikes reduction. As a case study for the formulation, the IEEE nine-bus, load curve of Mid-Atlantic region of the New York network is used to compare local prices in the system with and without emergency demand response program (EDRP). The study results demonstrate the effectiveness of these programs in an electricity market and showing them as appropriate tools in managing the LMPs of the power market more efficiently.

12/00693 A methodology for calculating the levelized cost of electricity in nuclear power systems with fuel recycling

De Roo, G. and Parsons, J. E. *Energy Economics*, 2011, 33, (5), 826–839.

This paper shows how the traditional definition of the levelized cost of electricity (LCOE) can be extended to alternative nuclear fuel cycles in which elements of the fuel are recycled. In particular, the LCOE is defined for a cycle with full actinide recycling in fast reactors in which elements of the fuel are reused an indefinite number of times. To the best of the authors' knowledge, this is the first LCOE formula for this cycle. Others have approached the task of evaluating this cycle using an 'equilibrium cost' concept that is different from a levelized cost. It is also shown how the LCOE implies a unique price for the recycled elements. This price reflects the ultimate cost of waste disposal postponed through the recycling, as well as other costs in the cycle. The authors demonstrate the methodology by estimating the LCOE for three classic nuclear fuel cycles: (i) the traditional once-through cycle, (ii) a twice-through cycle, and (iii) a fast reactor recycle. Given the chosen input parameters, the authors show that the 'equilibrium cost' is typically larger than the levelized cost, and explain why.

12/00694 A research on short term load forecasting problem applying improved grey dynamic model

Li, G.-D. *et al. International Journal of Electrical Power & Energy Systems*, 2011, 33, (4), 809–816.

The grey dynamic model GM(1, 1), which is based on the grey system theory, has recently emerged as a powerful tool for short-term load forecasting (STLF) problem. However, GM(1, 1) is only a first-order single variable grey model, the forecasted accuracy is unsatisfactory when original data show great randomness. This paper proposes an improved grey dynamic model GM(2, 1), a second-order single variable grey model, to enhance the forecasted accuracy. Then it is applied to improve STLF performance. The authors provide a viewpoint that the derivative and background value of GM(2, 1) model can be expressed in grey number. Then cubic spline function is presented to calculate the derivative and background value in grey number interval. They call the proposed model as 3spGM(2, 1) model. Additionally, the Taylor approximation method is applied to 3spGM(2, 1) for achieving the high forecasted accuracy. The improved version is defined as T-3spGM(2, 1). The power system load data of ordinary and special days are used to validate the proposed model. The experimental results showed that the proposed model has better performance for STLF problem.

12/00695 Accelerated electricity conservation in Juneau, Alaska: a study of household activities that reduced demand 25%

Leighty, W. and Meier, A. *Energy Policy*, 2011, 39, (5), 2299–2309.

An avalanche destroyed the main hydroelectric transmission line to Juneau, Alaska in April, 2008. Diesel-generated electricity was substituted, causing electricity prices to increase 500% for 45 days. Electricity demand fell by 25% during the supply disruption. Most of the reduction occurred before the higher rates were implemented. Some conservation – about 8% of historic consumption – persisted after the transmission line was repaired and prices returned to normal. Consumers reduced energy use through a combination of new habits and technical improvements. A survey of residential consumers indicated that the average household undertook 10 conservation actions, with major changes in lighting, space heating, fuel switching, and water and appliance use. A method is proposed for prioritizing conservation actions, for promotion according to their impact in electricity savings (as a function of popularity, effectiveness, and persistence) and a dynamic framework for electricity use before, during, and after a supply disruption (i.e. both the magnitude and rates of change in electricity conservation).

12/00696 An investigation of a household size trigeneration running with hydrogen

Wang, Y. *et al. Applied Energy*, 2011, 88, (6), 2176–2182.

This study examined the performance and emission characteristics of a household size trigeneration based on a diesel engine generator fuelled with hydrogen comparing to that of single generation, cogeneration using ECLIPSE simulation software. In single generation simulation, the engine genset is used to produce electricity only and the heat from the engine is rejected to the atmosphere. In cogeneration and trigeneration, in addition to the electricity generated from the genset, the waste heat rejected from the hot exhaust gases and engine cooling system, is captured for domestic hot water supply using heat exchangers and hot water tank; and a part of the waste heat is used to drive absorption cooling in trigeneration. Comparisons have been made for the simulated results of these three modes of operation for hydrogen and diesel. The results prove that hydrogen is a potential energy vector in the future, which is a key to meeting upcoming stringent greenhouse gases emissions. The study show that hydrogen has very good prospects to achieve a better or equal performance to conventional diesel fuel in terms of energetic performance, and a near zero carbon emission, depending on the life cycle analysis of the way the hydrogen is produced. The results also show enormous potential fuel savings and massive reductions in greenhouse gas emissions per unit of useful energy outputs with cogeneration and trigeneration compared with that of single generation.

12/00697 Challenges and options for a large wind power uptake by the European electricity system

Purvins, A. *et al. Applied Energy*, 2011, 88, (5), 1461–1469.

The contribution of renewable energies (in particular of wind power) to the electrical power generation has been continuously increasing in the recent decades. This article focuses on the necessary options that manage the variability of wind turbine output and enable the large scale integration of wind power with the current electricity system, such as additional power reserves, distributed storage technologies, in particular electric vehicles, and cross-border power transmission. The influence of geographical distribution of wind turbines on the produced power variability is described as well. The article highlights that even though state-of-art technologies for higher wind integration are present, there is a necessity for the proper management and integration of mentioned options.

12/00698 Cogeneration planning under uncertainty. Part I: multiple time frame approach

Carpaneto, E. *et al. Applied Energy*, 2011, 88, (4), 1059–1067.

Cogeneration system planning spans a multi-year time interval and is affected by various sources of uncertainty, mainly depending on the evolution of energy loads and prices. The high level of uncertainty requires assessing the convenience of adopting predefined technological alternatives in different scenarios of variation of the uncertain variables. This paper introduces an original framework based on identifying the characteristics of small-scale and large-scale uncertainties, whereby a comprehensive approach based on multiple (long-, medium- and short-term) time frames is formulated. Medium-term time periods exhibiting small variations of both electrical and thermal load patterns are grouped together and represented through electrical/thermal load and electricity price correlated random variables (RVs). A Monte Carlo simulation of the cogeneration plant operation is carried out in the short-term by extracting the RVs for each group from multivariate normal probability distributions. Multi-year scenarios in the long-term time frame are addressed in part II. The proposed approach is applied to a real energy system.

12/00699 Cogeneration planning under uncertainty. Part II: decision theory-based assessment of planning alternatives

Carpaneto, E. *et al. Applied Energy*, 2011, 88, (4), 1075–1083.

This paper discusses specific models and analyses to select the best cogeneration planning solution in the presence of uncertainties on a long-term time scale, completing the approach formulated in part I. The most convenient solutions are identified among a pre-defined set of planning alternatives according to decision theory-based criteria, upon definition of weighted scenarios and by using the exceeding

probabilities of suitable economic indicators as decision variables. Application of the criteria to a real energy system with various technological alternatives operated under different control strategies is illustrated and discussed. The results obtained show that using the net present cost indicator it is always possible to apply the decision theory concepts to select the best planning alternative. Other economic indicators like discounted payback period and internal rate of return exhibit possible application limits for cogeneration planning within the decision theory framework.

12/00700 Data analysis and short term load forecasting in Iran electricity market using singular spectral analysis (SSA)
Afshar, K. and Bigdeli, N. *Energy*, 2011, 36, (5), 2620–2627.
In this paper, the data analysis and short-term load forecasting (STLF) in Iran electricity market has been considered. The proposed method is an improved singular spectral analysis (SSA) method. SSA decomposes a time series into its principal components, i.e. its trend and oscillation components, which are then used for time series forecasting, effectively. The employed data are the total load time series of Iran electricity market in its real size and is long enough to make it possible to take properties such as non-stationary and annual periodicity of the market into account. Simulation results show that the proposed method has a good ability in characterizing and prediction of the desired load time series in comparison with some other related methods.

12/00701 Does increasing energy or electricity consumption improve quality of life in industrial nations?
Mazur, A. *Energy Policy*, 2011, 39, (5), 2568–2572.
Among the world's nations, per capita energy and electricity consumption is highly correlated with diverse indicators of quality of life. This is often interpreted to mean that additional energy and electricity consumption causes improvements in life quality. Prior analyses of cross-sectional data question this interpretation for industrial nations that already have high per capita energy consumption. The present analysis with longitudinal data shows that among industrial nations, increases in per capita energy and electricity consumption over the past three decades are not associated with corresponding improvements in quality of life.

12/00702 Effective retrofitting of post-combustion CO_2 capture to coal-fired power plants and insensitivity of CO_2 abatement costs to base plant efficiency
Lucquiaud, M. and Gibbins, J. *International Journal of Greenhouse Gas Control*, 2011, 5, (3), 427–438.
Existing coal-fired power plants were not designed to be retrofitted with carbon dioxide post-combustion capture (PCC) and have tended to be disregarded as suitable candidates for carbon capture and storage on the grounds that such a retrofit would be uneconomical. Low plant efficiency and poor performance with capture compared to new-build projects are often cited as critical barriers to capture retrofit. Steam turbine retrofit solutions are presented that can achieve effective thermodynamic integration between a post-combustion CO_2 capture plant and associated CO_2 compressors and the steam cycle of an existing retrofitted unit for a wide range of initial steam turbine designs. The relative merits of these capture retrofit integration options with respect to flexibility of the capture system and solvent upgradability will be discussed. Provided that effective capture system integration can be achieved, it can be shown that the abatement costs (or cost per tonne of CO_2 to justify capture) for retrofitting existing units is independent of the initial plant efficiency. This then means that a greater number of existing power plants are potentially suitable for successful retrofits of post-combustion capture to reduce power sector emissions. Such a wider choice of retrofit sites would also give greater scope to exploit favourable site-specific conditions for CCS, such as ready access to geological storage.

12/00703 Facilitation of renewable electricity using price based appliance control in Ireland's electricity market
Finn, P. *et al. Energy*, 2011, 36, (5), 2952–2960.
Ireland's share of electricity generated from RES-E (renewable energy sources) is due to increase from 14.4% in 2009 to 40% in 2020. With this target predominantly fulfilled with wind generated electricity, the need for increased grid flexibility to facilitate this intermittent energy source is becoming ever more significant. As smart metering becomes available, demand side participation will be one option for achieving this flexibility. Using an immersion heated hot water tank as an example, this paper examines the impact that price optimized load scheduling has on the facilitation of wind generated electricity. To replicate real-world data availability, optimization is performed using day-ahead predicted prices while the results are calculated using final prices and metered generation data. The results demonstrate a correlation between the day-ahead predicted half-hourly price of electricity and real-time wind availability. This supports the use of price as a means of providing an incentive for load response in order to increase the amount of renewable energy that can be facilitated on the electrical grid. Furthermore, various thermal storage efficiencies were examined for the device to reveal that as the energy loss rate of the device is reduced, the financial savings increase, wind generation increases, and conventional generation decreases.

12/00704 Financing off-grid rural electrification: country case Nepal
Mainali, B. and Silveira, S. *Energy*, 2011, 36, (4), 2194–2201.
More than 61% of the total population of Nepal has no access to electricity. The majority is poor and live in rural areas. In recent years, rural electrification has had high priority in government policies, and micro hydro and solar PV have been the most commonly adopted off-grid technologies. The financial mix in the off-grid rural electrification is generally characterized by subsidy, equity and credit. This study analyses how rural electrification has been funded and the impact of subsidy policies on the renewable energy market, focusing on the projects implemented under the 'subsidy policy 2000'. This study is based on official data obtained from authorities in Nepal and a survey carried out among private supply and installation companies, NGOs and financial institutions. It shows that awareness levels in adopting RE-technologies and willingness of people to access and pay for electricity have increased significantly. However, there is a huge financial gap between the cost of electrification and the affordability. Bridging this gap is a crucial issue that needs to be addressed for the smooth expansion of rural electrification in the country.

12/00705 Households' self-selection of dynamic electricity tariffs
Ericson, T. *Applied Energy*, 2011, 88, (7), 2541–2547.
Offering electricity consumers' time-differentiated tariffs may reduce peak consumption if consumers choosing the tariffs are demand responsive. However, one concern is that time-differentiated tariffs may attract consumers who benefit without responding to the price, simply because they have a favourable consumption pattern. It is thus important to understand on which basis consumers choose between tariffs. The authors model the choice as a function of compensating welfare measures, and use a discrete choice model on data from a residential dynamic pricing experiment. The results indicate that higher demand flexibility will tend to increase the propensity to select dynamic tariffs, while consumption patterns do not influence tariff choice significantly.

12/00706 Households' willingness to pay for overhead-to-underground conversion of electricity distribution networks
McNair, B. J. *et al. Energy Policy*, 2011, 39, (5), 2560–2567.
Underground low-voltage electricity networks have several advantages over overhead networks including reliability of supply, safety and improved visual amenity. The economic viability of replacing existing overhead networks with new underground networks depends on the value of these benefits to households, but no complete value estimates are available in the literature. This paper represents a contribution towards addressing this research gap. A stated choice survey is used to estimate willingness to pay for undergrounding in established residential areas in Canberra, Australia. Average willingness to pay is at least A$6838 per household and there is significant variation in preferences over the population. The results suggest that benefits would be highest in areas with higher household income and older residents where visual amenity, safety, tree trimming, or restrictions on the use of yard space are of concern.

12/00707 Impact of different utilization scenarios of electric vehicles on the German grid in 2030
Hartmann, N. and Özdemir, E. D. *Journal of Power Sources*, 2011, 196, (4), 2311–2318.
Electric vehicles are commonly seen as one of the alternatives to reduce the oil dependency and the greenhouse gas emissions in the transport sector. The aim of this paper is to evaluate the impact of different electric vehicle charging strategies on the national grid including the storage utilization of electric vehicles (V2G-vehicle to grid). Furthermore, an economic analysis of electric vehicle utilization is performed and the results are compared with the conventional diesel vehicle. To accomplish this aim the availability of passenger cars in Germany to be plugged into the grid showed to be high at any time over the day (>89%), which is advantageous for the V2G concept. The impact of the different electric vehicle charging strategies is investigated by employing three scenarios. The first scenario (unmanaged charging) shows that 1 million electric vehicles only impacts slightly on the daily peak electricity demand. In the second scenario (grid stabilizing storage use) a maximum reductions of grid fluctuations of 16% can be achieved with the use of 1 million electric vehicles as storage. The last scenario (profit maximization by power trading) the maximum daily revenues from V2G activities are calculated to be $€_{2009}0.68$.

12/00708 Impact of energy storage in buildings on electricity demand side management

Qureshi, W. A. *et al. Energy Conversion and Management*, 2011, 52, (5), 2110–2120.

This paper assesses impact of using phase change materials (PCM) in buildings to leverage its thermal energy storage capability. The emphasis is from an electricity demand side perspective with case studies that incorporates wholesale electricity market data of New Zealand. The results presented in this paper show that for space heating application significant advantages could be obtained using PCM built structures. These positive impacts include peak load shifting, energy conservation and reduction in peak demand for network line companies and potential reduction in electricity consumption and savings for residential customers. This paper uses a testing facility that consists of two identically designed and shaped offices built at Tamaki Campus location of the University of Auckland, New Zealand. The walls and ceilings of one office are finished with ordinary gypsum boards while the interior of the other office is finished with PCM-impregnated gypsum boards. Controlled heating facility is provided in both the offices for maintaining temperature within the range of human comfort. This facility is equipped with advanced data acquisition equipment for data monitoring and archiving both locally within the offices and also remotely. Through actual observations and analysis this paper demonstrates two major impacts of DSM. First, the application of phase change material (PCM) in building environment enabling efficient thermal storage to achieve some reduction in the overall electrical energy consumption. Second, assessment of peak load shifting achieved for space heating in a PCM building during a typical winter period in New Zealand.

12/00709 Integration of trigeneration in an indirect cascade refrigeration system in supermarkets

Marimón, M. A. *et al. Energy and Buildings*, 2011, 43, (6), 1427–1434.

This article presents an energy and economic analysis of a trigeneration configuration for supermarket applications. The energy system in a supermarket is relatively complex, because it includes lighting, air conditioning, cabinets, refrigeration system, etc. A trigeneration system could be used to simultaneously satisfy heating, refrigeration and electricity demands in supermarkets. More specifically, this article studies the integration of a trigeneration system and an indirect refrigeration cascade compression system in a supermarket in Barcelona. The trigeneration system consists of a cogeneration engine and an ammonia/water absorption chiller unit. The results of simulating energy usage, life cycle costs and CO_2 emissions have been compared with a conventional indirect refrigeration cascade compression system for the supermarket studied. Several trigeneration configurations have been studied. They all show a payback time of less than 6 years but the profitability of the investment depends strongly on the ratio between the prices of natural gas and electricity. This study shows that this novel trigeneration system is economically feasible and environmentally more viable than conventional supermarket systems.

12/00710 On-grid electricity tariffs in China: development, reform and prospects

Ma, J. *Energy Policy*, 2011, 39, (5), 2633–2645.

With the introduction of market-oriented measures in China's power sector in the mid-1980s, electricity sale prices to the grid companies – on-grid electricity tariffs – became the focus of the energy industry, thus affecting all related stakeholders, including fuel suppliers, power generators and end-use consumers. A number of changes have gradually been undertaken in terms of electricity tariff settings and their implementation to address specific requirements of the expansion of the power industry at each stage of its development. On-grid electricity tariffs had been used as a key lever to attract investment in power generation at an early stage of reform and then to encourage competition in the power industry. In response to the rising concerns about environmental protection and the promotion of clean energy utilization, tariffs have progressively been developed for renewable electricity generation, which has contributed to massive expansion of the renewable power industry in China. This paper reviews key milestones of the development of on-grid electricity tariffs in China, examines the tariff-setting mechanisms of coal-fired power plants and renewable power generation, analyses the factors associated with the adjustments of the tariff levels and discusses the options for further reform and more effective electricity pricing.

12/00711 Pan-European management of electricity portfolios: risks and opportunities of contract bundling

Gampert, M. and Madlener, R. *Energy Policy*, 2011, 39, (5), 2855–2865.

Due to the liberalization of energy markets in the European Union, today's European utilities not only focus on electricity supply, but also offer exchange-traded 'structured products' or portfolio management for unbundling financial and physical risk positions. Many utilities are only able to provide these services in their domestic markets. In a globalized economy, the need for a centrally organized pan-European portfolio management has arisen, as it allows a simplified commodity sourcing in combination with an optimized risk management. This study examines the challenges to be overcome for establishing a European-wide bundling of electricity contracts. For this purpose, a case study based on the business perspective of RWE supply & trading in Central and Eastern Europe is carried out. In a first step, general requirements for a pan-European bundling of electricity contracts are analysed. Then, RWE's situation in Europe is examined, based on which the authors finally propose a concept to meet customer demands in Central and Eastern Europe.

12/00712 Paradigm shift in urban energy systems through distributed generation: methods and models

Manfren, M. *et al. Applied Energy*, 2011, 88, (4), 1032–1048.

The path towards energy sustainability is commonly referred to the incremental adoption of available technologies, practices and policies that may help to decrease the environmental impact of energy sector, while providing an adequate standard of energy services. The evaluation of trade-offs among technologies, practices and policies for the mitigation of environmental problems related to energy resources depletion requires a deep knowledge of the local and global effects of the proposed solutions. While attempting to calculate such effects for a large complex system like a city, an advanced multi-disciplinary approach is needed to overcome difficulties in modelling correctly real phenomena while maintaining computational transparency, reliability, interoperability and efficiency across different levels of analysis. Further, a methodology that rationally integrates different computational models and techniques is necessary to enable collaborative research in the field of optimization of energy efficiency strategies and integration of renewable energy systems in urban areas. For these reasons, a selection of currently available models for distributed generation planning and design is presented and analysed in the perspective of gathering their capabilities in an optimization framework to support a paradigm shift in urban energy systems. This framework embodies the main concepts of a local energy management system and adopts a multicriteria perspective to determine optimal solutions for providing energy services through distributed generation.

12/00713 Price forecasting of day-ahead electricity markets using a hybrid forecast method

Shafie-khah, M. *et al. Energy Conversion and Management*, 2011, 52, (5), 2165–2169.

Energy price forecasting in a competitive electricity market is crucial for the market participants in planning their operations and managing their risk, and it is also the key information in the economic optimization of the electric power industry. However, price series usually have a complex behaviour due to their non-linearity, non-stationarity, and time variancy. In this paper, a novel hybrid method to forecast day-ahead electricity price is proposed. This hybrid method is based on wavelet transform, auto-regressive integrated moving average (ARIMA) models and radial basis function neural networks (RBFN). The wavelet transform provides a set of better-behaved constitutive series than price series for prediction. ARIMA model is used to generate a linear forecast, and then RBFN is developed as a tool for non-linear pattern recognition to correct the estimation error in wavelet-ARIMA forecast. Particle swarm optimization (PSO) is used to optimize the network structure which makes the RBFN be adapted to the specified training set, reducing computation complexity and avoiding overfitting. The proposed method is examined on the electricity market of mainland Spain and the results are compared with some of the most recent price forecast methods. The results show that the proposed hybrid method could provide a considerable improvement for the forecasting accuracy.

12/00714 Rethinking real-time electricity pricing

Allcott, H. *Resource and Energy Economics*, 2011, 33, (4), 820–842.

Most US consumers are charged a near-constant retail price for electricity, despite substantial hourly variation in the wholesale market price. This paper evaluates the first program to expose residential consumers to hourly real-time pricing (RTP). It is found that enrolled households are statistically significantly price elastic and that consumers responded by conserving energy during peak hours, but remarkably did not increase average consumption during off-peak times. The program increased consumer surplus by $10 per household per year. While this is only 1–2% of electricity costs, it illustrates a potential additional benefit from investment in retail smart grid applications, including the advanced electricity meters required to observe a household's hourly consumption.

12/00715 Selection of typical days for the characterisation of energy demand in cogeneration and trigeneration optimisation models for buildings

Ortiga, J. *et al. Energy Conversion and Management*, 2011, 52, (4), 1934–1942.

Optimization models are commonly used in analysing and selecting the optimal configuration of a cogeneration or trigeneration system. Due to the high variability of energy demand in the residential and tertiary sector, hourly demand data is needed in order to accurately analyse and optimize energy supply systems, but a very high number of hours leads to very high or unfeasible computational time expenses. To overcome this problem, the most common practice is to reduce the number of days used in the optimization model working only with typical days, but there are no guidelines on how to select these days and it is not clear if these typical days properly represent the whole year in the optimization model. This study proposes a method for the selection of typical days of hourly energy demand for a whole year and analyses the influence of the results on an optimization model for a trigeneration system. Heating and cooling energy demand data has been obtained from energy simulation software for buildings and an optimization model for a trigeneration system has been developed. The optimization of the whole year is then compared with the optimization of the selected typical days. The results using typical days are very similar to the results of the whole year.

12/00716 Small scale impact of gas technologies on electric load management – μCHP & hybrid heat pump
Vuillecard, C. *et al. Energy*, 2011, 36, (5), 2912–2923.
To face winter electricity peaking issues the authors proposes an analysis of the potential of distributed gas technologies for demand side management. This impact has to be analysed at small scale before any large-scale extrapolation. Bi-energy technologies (gas and electricity) are a path to transfer loads from one system to another. Indeed, the flexible gas infrastructure adapts to load while electricity demand variations cause risk of black-out. The impacts of two hybrid technologies are studied at transformer level with 1-min experimental load profiles of 40 dwellings equipped with micro combined heat and power (μCHP) boilers over a year in France. An absolute peak load reduction by 17% at small scale is found. Different technology mixes are then simulated to assess the effect on local infrastructure. Finally a methodology for temperature dependence analysis of load is used to assess different potential benefits of gas technologies.

12/00717 The impact of the European Union emission trading scheme on the electricity-generation sector
Kirat, D. and Ahamada, I. *Energy Economics*, 2011, 33, (5), 995–1003.
In order to comply with their commitments under the Kyoto Protocol, France and Germany participate in the European Union emission trading scheme (EU ETS) which predominantly concerns the electricity-generation sectors. This study considers whether the EU ETS provides the appropriate economic incentives to produce an efficient system in line with the Kyoto Protocol commitments. If so, electricity producers in the countries concerned should include the price of carbon in their cost functions. After identifying different sub-periods of the EU ETS during its pilot phase (2005–2007), the prices of various electricity contracts in France and Germany were modelled and the volatility of electricity prices around their fundamentals considered while evaluating the correlation between electricity prices in the two countries. Electricity producers in both countries were found to be constrained to include the carbon price in their cost functions during the first 2 years of the EU ETS. Over this period, German electricity producers were more constrained than their French counterparts, and the inclusion of the carbon price in the electricity-generation cost function was much more stable in Germany than in France. Evidence was also found of fuel switching in electricity generation in Germany after the collapse of the carbon market. Furthermore, the European market for emission allowances has greatly contributed to the partial alignment of the wholesale price of electricity in France to that in Germany.

12/00718 Understanding the design and economics of distributed tri-generation systems for home and neighborhood refueling – part I: single family residence case studies
Li, X. and Ogden, J. M. *Journal of Power Sources*, 2011, 196, (4), 2098–2108.
The potential benefits of hydrogen as a transportation fuel will not be achieved until hydrogen vehicles capture a substantial market share. However, although hydrogen fuel cell vehicle (FCV) technology has been making rapid progress, the lack of a hydrogen infrastructure remains a major barrier for FCV adoption and commercialization. The high cost of building an extensive hydrogen station network and the foreseeable low utilization in the near term discourages private investment. Based on the past experience of fuel infrastructure development for motor vehicles, innovative, distributed, small-volume hydrogen refuelling methods may be required to refuel FCVs in the near term. Among small-volume refuelling methods, home and neighbourhood tri-generation systems (systems that produce electricity and heat for buildings, as well as hydrogen for vehicles) stand out because the technology is available and has potential to alleviate consumer's fuel availability concerns. In addition, it has features attractive to consumers such as convenience and security to refuel at home or in their neighbourhood. The objective of this paper is to provide analytical tools for various stakeholders such as policy makers, manufacturers and consumers, to evaluate the design and the technical, economic, and environmental performances of tri-generation systems for home and neighbourhood refuelling. An interdisciplinary framework and an engineering/economic model is developed and applied to assess home tri-generation systems for single-family residences (case studies on neighbourhood systems will be provided in a later paper). Major tasks include modelling yearly system operation, exploring the optimal size of a system, estimating the cost of electricity, heat and hydrogen, and system CO_2 emissions, and comparing the results to alternatives. Sensitivity analysis is conducted, and the potential impacts of uncertainties in energy prices, capital cost reduction (or increase), government incentives and environmental cost are evaluated. Policy implications of the modelling results are also explored.

07 STEAM RAISING

Boiler operation/design

12/00719 Cost efficiency of Japanese steam power generation companies: a Bayesian comparison of random and fixed frontier models
Assaf, A. G. *et al. Applied Energy*, 2011, 88, (4), 1441–1446.
This study analyses and compares the cost efficiency of Japanese steam power generation companies using the fixed and random Bayesian frontier models. The authors show that it is essential to account for heterogeneity in modelling the performance of energy companies. Results from the model estimation also indicate that restricting CO_2 emissions can lead to a decrease in total cost. The study finally discusses the efficiency variations between the energy companies under analysis, and elaborates on the managerial and policy implications of the results.

12/00720 Estimation of maximum steam pressure by a mathematical linear technique
Kralj, A. K. *Energy*, 2011, 36, (5), 2434–2439.
This paper presents a method for estimating the maximum pressure of steam which can be generated in recovering heat from individual processes, by partial linearization of the grand-composite curve. The technique is based on the pinch-analysis method by using a grand-composite curve (GCC), which can be approximated by using a mathematical function. The mathematical linear technique is composed of two steps. First step, analysing the possibility of additionally-available heat flow rate integration from different processes into one basic process. Second step, estimating the maximum possible steam-pressure to be generated. This linear technique was applied in an existing silver and oxide formalin process, resulting in generation of more steam with higher steam-pressure, thus producing an additional profit of €183,900 per year.

12/00721 Existing large steam power plant upgraded for hydrogen production
Galanti, L. *et al. Applied Energy*, 2011, 88, (5), 1510–1518.
This paper presents and discusses the results of a complete thermo-economic analysis of an integrated power plant for co-production of electricity and hydrogen via pyrolysis and gasification processes fed by various coals and mixture of coal and biomass, applied to an existing large steam power plant (ENEL Brindisi power plant – 660 MW_e). Two different technologies for the syngas production section are considered: pyrolysis process and direct pressurized gasification. Moreover, the proximity of a hydrogen production and purification plants to an existing steam power plant favours the inter-exchange of energy streams, mainly in the form of hot water and steam, which reduces the costs of auxiliary equipment. The high quality of the hydrogen would guarantee its usability for distributed generation and for public transport. The results were obtained using WTEMP thermoeconomic software, developed by the thermochemical power group of the University of Genoa, and this project has been carried out within the framework of the FISR national project 'Integrated systems for hydrogen production and utilization in distributed power generation'.

12/00722 Steam carbon gasification of a nickel based oxygen carrier
Chiron, F.-X. and Patience, G. S. *Fuel*, 2011, 90, (7), 2461–2466.
Ni-based oxygen carriers are promising candidates for Chemical looping applications due to a combination of excellent methane conversion performance, mechanical stability, oxygen transfer capacity. However, experiments conducted on $NiO/NiAl_2O_4$ in a micro-fluidized bed reactor show that methane forms coke on active nickel sites. In subsequent tests, water vapour was fed to the coked Ni oxygen carrier producing a highly concentrated stream of CO/H_2 (1/1). In the absence of water vapour, production of hydrogen dropped with time while a methane/argon mixture was fed to the reactor. Co-feeding water together with methane improves stability – both H_2 production and carbon deposition were constant for over 1 h. Despite the tremendous lay down of carbon, catalytic activity remained stable at levels as low as 3 vol.% water vapour (and 10% methane). Water vapour is an effective oxidant for Ni(0) but is insufficient to entirely re-oxidize the oxygen carrier from Ni to NiO.

12/00723 Thermoeconomic optimisation of heat recovery steam generators of combined cycle gas turbine power plants considering off-design operation
Rovira, A. *et al. Energy Conversion and Management*, 2011, 52, (4), 1840–1849.
One of the practical uses of the thermoeconomic models is to find a trade-off between efficiency and cost in the design of a power plant. Usually, the thermoeconomic analyses involve a thermodynamic model of the power plant and an economic model dedicated to assess the costs. In combined cycle gas turbine (CCGT) power plants, the thermodynamic model usually calculates the performance and the energy balances of the power plant at the design conditions. However, nowadays, after several years of CCGTs operation experience, data of annual operation may be found, which differ to some extent from the design conditions. This paper shows a methodology to achieve thermoeconomic optimizations of CCGT power plants taking into account the frequent off-design operation of the plant. Therefore, the aim of the work is to improve the thermoeconomic design of the power plant by means of considering a more realistic annual operation scenario. In addition, the methodology is applied to optimize several CCGT configurations operating under different scenarios of energy production. The results of the optimizations are compared to those obtained with usual thermoeconomic models based on design conditions performance.

08 COMBUSTION

Burners, combustion systems

12/00724 Ash partitioning during the oxy–fuel combustion of lignite and its dependence on the recirculation of flue gas impurities (H_2O, HCl and SO_2)
Jiao, F. *et al. Fuel*, 2011, 90, (6), 2207–2216.
Oxy–fuel combustion of a brown coal (i.e. lignite) has been carried out at 1000 °C to experimentally examine the vaporization of organically bound metals and the agglomeration of ash particles as a function of the concentration of gaseous impurities including H_2O, HCl and SO_2 in ~27% O_2 balanced with CO_2. The properties of bulk ash and individual metals were investigated intensively. Particularly, attention was paid to Na which is notorious for fouling and to organically bound Al which has been less studied. The results indicate that, the organically bound metals, although possessing a very low content in the raw coal, are vital for the agglomeration of ash particles, which are also highly sensitive to the loading of gas impurities in flue gas. HCl recirculation is the most crucial factor promoting the vaporization of metals via chlorination. Apart from alkali metals, the organically bound Al and Ti were also vaporized noticeably. Recirculation of SO_2 promoted the sulfation of Na to condense into liquid droplet which increased fine ash yield. Co-existence of bulk HCl and SO_2 played a synergetic role in the sufation of Na via an initial chlorination of the char-bound Na. In contrast, co-existence of steam with HCl and SO_2 favoured the formation of Na alumino-silicates, which are favourable for ash agglomeration.

12/00725 Co-firing characteristics of rice husk and coal in a cyclonic fluidized-bed combustor (Ψ-FBC) under controlled bed temperatures
Madhiyanon, T. *et al. Fuel*, 2011, 90, (6), 2103–2112.
This study extensively investigated temperature and emission characteristics, and the performance of co-firing rice husk with coal in a cyclonic fluidized-bed combustor (Ψ-FBC) of 125 kW_{th} nominal capacity. The Ψ-FBC integrated the distinct features of cyclonic/vortex and fluidized-bed combustion. Fluidization, without any inert material, can be accomplished by the stirring blades and vortex ring. The combustor was equipped with a multi-passes water coil to regulate the bed temperatures, varying 800–900 °C. Rice husk was co-fired with coal, a supplementary fuel, with coal blending ratios of 0–25% by thermal basis. The radial temperature profiles displayed vortex combustion along the wall, while the axial temperature profiles suggested a well-mixed condition in the lower part. The large depletion of O_2 and proliferation of CO in the lower part revealed vigorous combustion beneath the vortex ring. A reducing atmosphere appeared unfavourable to NO_x formation. The combustor showed satisfied E_c, mostly >98.5%. The optimum operating conditions with respect to NO_x emissions were: (1) the thermal percentage of coal not >20%, and (2) bed temperatures between 800 and 850 °C. Otherwise, NO_x emissions would exceed the regulations; even CO and SO_2 emissions were well acceptable.

12/00726 Design and development of a SPMB (self-aspirating, porous medium burner) with a submerged flame
Yoksenakul, W. and Jugjai, S. *Energy*, 2011, 36, (5), 3092–3100.
This work reports design and development of a SPMB (self-aspirating porous medium burner) for replacing the self-aspirating, CB (conventional gaseous fuel, free flame burners), which are widely used in heating process of SMEs (small and medium scale enterprises) in Thailand but they have relatively low thermal efficiency of about 30%. Design of the SPMB relies on the same important characteristics of the CB, i.e. using the same mixing tube and the same fuel nozzle. The SPMB is formed by a packed bed of alumina spheres. The pressure drop across the packed bed, diameter of particles and a combustion chamber diameter are estimated by Ergun's equation in combination with *Pe* (Peclet number). The SPMB yields a submerged flame with an intense thermal radiation emitted downstream. An output radiation efficiency as high as 23% can be achieved at relatively high turn-down ratio of 2.65 and firing rate ranging from 23 to 61 kW. The SPMB shows a more complete combustion with relatively low CO emission of less than 200 ppm and acceptably high NO_x emission of less than 98 ppm as compared with the CB throughout the range of firing rate studied, suggesting the possibility of the SPMB in replacing the CB.

12/00727 Detailed characterization of the pyrolytic liquids obtained by pyrolysis of sawdust
Sinağ, A. *et al. Journal of Analytical and Applied Pyrolysis*, 2011, 90, (1), 48–52.
Pyrolysis of sawdust was conducted in a tubular reactor. Yields of pyrolytic liquid, gas, and char were calculated. Pyrolytic liquids were characterized by using ^{1}H NMR, FTIR and elemental analysis. Pyrolytic liquids were diluted with water (1:10) since the intermediate compounds such as acids, aldehydes, furfurals and phenols were highly water-soluble. The acid, aldehyde, and furfural contents of the aqueous phases were analysed by using an ion chromatograph equipped with and high-performance liquid chromatography pump, while amounts of the phenols were determined by using UV–vis spectrometer. The results show that pyrolytic liquids contain mainly aliphatic structures (55–59 vol.%). The acetic (13–31 mg/g sawdust) and formic acid (8–18 mg/g sawdust) amounts of the pyrolytic liquids found are significantly higher than those of other intermediates.

12/00728 Droplet size distribution and evaporation characteristics of fuel spray by a swirl type atomizer
Li, T. *et al. Fuel*, 2011, 90, (7), 2367–2376.
Spray atomization and evaporation play extremely important roles in mixture formation and combustion processes of direct injection (DI) gasoline engines. In this study, the fundamental characteristics of a swirl spray injected into a constant volume vessel are investigated by means of several laser diagnostic techniques including the laser diffraction-based method for droplet size distribution, the laser induced fluorescence–particle image velocimetry for velocity distributions of droplets and spray-induced ambient air flow, and the two-wavelength laser absorption–scattering technique for concentration distributions of liquid and vapour phases in the spray. The results show that the droplets at outer zone of the spray exhibit larger diameter than those at inner zone under both ambient pressures 0.1 and 0.4 MPa. While this can be partially attributed to the effect of spray-induced ambient air flow, the strength of ambient air flow become small when increasing the ambient pressure from 0.1 to 0.4 MPa, indicating the strong influence of spray dynamics on the droplet size distribution. In the evaporating spray, there are higher vapour concentrations near the spray axis than at peripheral zones. At 4.0 ms after start of injection, spray droplets almost completely evaporate under ambient temperature 500 K and pressure 1.0 MPa, but there are significantly amount of

fuels with equivalence ratio below 0.5 in the spray. Reduction in ambient pressure promotes the air entrainment and droplet evaporation, but lowered ambient pressure results in more fuel vapour of equivalence ratio above 1.3 along the spray axis.

12/00729 Economic tradeoff between biochar and bio-oil production via pyrolysis

Yoder, J. *et al. Biomass and Bioenergy*, 2011, 35, (5), 1851–1862.

This paper examines some of the economic tradeoffs in the joint production of biochar and bio-oil from cellulosic biomass. The pyrolysis process can be performed at different final temperatures, and with different heating rates. While most carbonization technologies operating at low heating rates (large biomass particles) result in higher yields of charcoal, fast pyrolysis (which processes small biomass particles) is the preferred technology to produce bio-oils. Varying operational and design parameters can change the relative quantity and quality of biochar and bio-oil produced for a given feedstock. These changes in quantity and quality of both products affect the potential revenue from their production and sale. The authors estimate quadratic production functions for biochar and bio-oil. The results are then used to calculate a product transformation curve that characterizes the yields of bio-oil and biochar that can be produced for a given amount of feedstock, movement along the curve corresponds to changes in temperatures, and it can be used to infer optimal pyrolysis temperature settings for a given ratio of biochar and bio-oil prices.

12/00730 Effects of ultra-high injection pressure and micro-hole nozzle on flame structure and soot formation of impinging diesel spray

Wang, X. *et al. Applied Energy*, 2011, 88, (5), 1620–1628.

The effects of ultra-high injection pressure (P_{inj} = 300 MPa) and micro-hole nozzle (d = 0.08 mm) on flame structure and soot formation of impinging diesel spray were studied with a high-speed video camera in a constant volume combustion vessel. Two-colour pyrometry was used to measure the line-of-sight soot temperature and concentration with two wavelengths of 650 and 800 nm. A flat wall vertical to the injector axis is located 30 mm away from the injector nozzle tip to generate impinging spray flame. Three injection pressures of 100, 200 and 300 MPa and two injector nozzles with diameters of 0.16 and 0.08 mm were used. With the conventional injector nozzle (0.16 mm), ultra-high injection pressure generates appreciably lower soot formation. With the micro-hole nozzle (0.08 mm), impinging spray flame shows much smaller size and lower soot formation at the injection pressure of 100 MPa. The soot formation is too weak to be detected with the micro-hole nozzle at injection pressures of 200 and 300 MPa. With eliminating the impact of injection rate on soot level, both ultra-high injection pressure and micro-hole nozzle have an obvious effect on soot reduction. Soot formation characteristics of impinging spray flame were compared with those of free spray flame using both the conventional and micro-hole nozzles. With the conventional nozzle, flat wall impingement deteriorates soot formation significantly. While soot formation characteristics of free spray flame with the micro-hole nozzle are not altered obviously by flat wall. Liquid length of the 0.16 mm nozzle is longer than the impingement distance and liquid length of the 0.08 mm nozzle is shorter than the impingement distance. Liquid impingement upon the wall is responsible for the deteriorated soot level of impinging flame compared to that of free flame with the conventional nozzle.

12/00731 Energy and exergy analyses of a mixed fuel-fired grate–kiln for iron ore pellet induration

Zhang, Y. *et al. Energy Conversion and Management*, 2011, 52, (5), 2064–2071.

Many models of iron ore pellet induration have been developed on the basis of the first law of thermodynamics. However, the exergy analysis, well grounded on the first and second law, of the process is rare. Therefore, exergy balance test was systematically carried out on a grate–kiln, and energy and exergy analyses have been conducted to investigate irreversibility of the process. A model of iron oxide pellet exergy (IOPEM) is presented according to oxidation kinetic characteristics. It is found that the maximum effect (−6.8%) of the characteristics on the pellet exergy appears in the raised end of the kiln. The exergy efficiency of the system is determined to be 10.7% whereas its energy efficiency 59.9%, indicating a great potential for energy-saving improvements. The exergy analysis reveals exergy destruction ratio of kiln and cooler is 14.1%, and 7.7% respectively, and the largest exergy destruction (74.2%) results from the grate. No violent effect of reference environment temperature on exergy efficiency of major components is observed, indicating the grate is the major source of irreversibility. In a word, this study provides a better understanding of the energy and exergy flows of iron ore pellet induration in the grate–kiln and helps to economize energy.

12/00732 Flame stability studies in a hydrogen–air premixed flame annular microcombustor

Jejurkar, S. Y. and Mishra, D. P. *International Journal of Hydrogen Energy*, 2011, 36, (12), 7326–7338.

Flame stability in an annular heat recirculating microcombustor burning stoichiometric hydrogen–air mixture was explored by means of a rigorous thermal analysis. The analysis is based on computational fluid dynamics model of reacting fluid flow accounting for interactions in flow, species, and conjugate thermal field in fluid and solid. Consideration of thermal diffusion effects in the model was necessary for realistic predictions in all the cases. Flame stability under different inlet velocity and wall thermal conductivities was studied. Results showed that a stable flame could stabilize in this combustor in the velocity range of 3–35 m/s. However, the upper stability limit widened for lower wall thermal conductivity. Low velocity flashback and high velocity blowout bounded the stability region with respect to inlet velocity for lower thermal conductivity wall material. Lower flame stability limit was influenced by thermal design of the microcombustor that prevented flame extinction and ability of flame to stabilize at the heated wall even at higher inlet velocity controlled the upper flame stability limit. Flame established well within the combustor for the lowest wall thermal conductivity without blowout and approached flashback for the highest conductivity when wall thermal conductivity was varied at constant inlet velocity. The relative importance of axial and radial wall heat conduction in flame stabilization was explored at the extremes of operating conditions. Both the components played equally important roles in flame stabilization by influencing heat recirculation and losses within the microcombustor. A suitable combination of structural materials could provide a stable flame with high surface temperatures in a lightweight system.

12/00733 Fragmentation and diffusion model for coal pyrolysis

Chen, Y. and He, R. *Journal of Analytical and Applied Pyrolysis*, 2011, 90, (1), 72–79.

A coal pyrolysis model is presented to describe fragmentation and diffusion of coal particles. This model combines chemical reactions and volatile matter diffusion inside the coal pores with the released primary products undergoing secondary reactions while the volatile matter diffuses inside the pores. Numerical simulations with the model show that the tar diffusivity significantly influences the final coal pyrolysis yields. The model qualitatively describes some mechanisms combining pore diffusion and secondary reactions in coal pyrolysis. The model explains high volatile releases at high temperatures and how coals with similar initial chemical compositions have different final yields in the same pyrolysis environment.

12/00734 Laminar burning velocity predictions by meso-scale flames in an annular diverging tube

Kim, G. T. and Kim, N. I. *Fuel*, 2011, 90, (6), 2217–2223.

Flame behaviour in an annular diverging tube (ADT) consisting of an outer quartz tube and a tapered inner core column was investigated as a basic model for small combustion devices of various combustion space scales. Flames can be stabilized at suitable locations where the mean flow velocity is matched to the spatial average propagation velocity (SAPV). Transient variations of wall temperature and the SAPV were compared for various experimental parameters: inner core materials, burner configurations, and flow rates. It was found that a critical propagation velocity (CPV) exists that is least affected by the flow rates. The CPVs of methane, propane, and dimethyl ether (DME) were measured and a good agreement was shown between the measured CPVs and the laminar burning velocities presented in the literatures. Therefore, the ADT method can be a model for small combustion devices of various combustion space scales; furthermore, this study can be beneficial in designing and operating small combustion devices. The ADT method can also be applied in the field for *in situ* monitoring of the burning velocities.

12/00735 Large eddy simulation and preliminary modeling of the flow downstream a variable geometry swirler for gas turbine combustors

Eldrainy, Y. A. *et al. International Communications in Heat and Mass Transfer*, 2011, 38, (8), 1104–1109.

This work presents a novel swirler with variable blade configuration for gas turbine combustors and industrial burners. The flow dynamics downstream the swirler was explored using large eddy simulation (LES). The resolved turbulence kinetic energy in the region where the flow exhibits the main flow phenomena was well above 80% of the total turbulent kinetic energy of the flow. It was shown that the new swirler produces a central recirculation zone and a Rankine vortex structure which are necessary for swirl flame stabilization. Two Reynolds-averaged Navier–Stokes (RANS) simulation cases utilizing the standard and realizable k–ε turbulence models were also conducted for two objectives. The first is to demonstrate the validity of RANS/eddy-viscosity models in predicting the main characteristics of swirling flows

with comparison to the LES results. The second objective is to comparatively investigate the flow features downstream the new swirler in both co-rotating and counter-rotating blade configurations. The results show that the counter-rotating configuration produces higher turbulence kinetic energy and more compact recirculation zone compared to the co-rotating configuration.

12/00736 Numerical simulation of a hydrogen fuelled gas turbine combustor

Gobbato, P. *et al. International Journal of Hydrogen Energy*, 2011, 36, (13), 7993–8002.

The interest for hydrogen-fuelled combustors is recently growing thanks to the development of gas turbines fed by high content hydrogen syngas. The diffusion flame combustion is a well-known and consolidated technology in the field of industrial gas turbine applications. However, few CFD analyses on commercial medium size heavy duty gas turbine fuelled with pure hydrogen are available in the literature. This paper presents a CFD simulation of the air-hydrogen reacting flow inside a diffusion flame combustor of a single shaft gas turbine. The three-dimensional geometrical model extends from the compressor discharge to the gas turbine inlet (both liner and air plenum are included). A coarse grid and a very simplified reaction scheme are adopted to evaluate the capability of a rather basic model to predict the temperature field inside the combustor. The interest is focused on the liner wall temperatures and the turbine inlet temperature profile since they could affect the reliability of components designed for natural gas operation. Data of a full-scale experimental test are employed to validate the numerical results. The calculated thermal field is useful to explain the non-uniform distribution of the temperature measured at the turbine inlet.

12/00737 Numerical studies on flame inclination in porous media combustors

Zheng, C. *et al. International Journal of Heat and Mass Transfer*, 2011, 54, (15–16), 3642–3649.

Inclinational instability developing during propagation of a filtration combustion wave in an inert porous medium is studied using two-dimensional numerical model. Stable and unstable combustion waves are generated by varying combustion parameters such as pressure, equivalence ratio, filtration velocity, effective conductivity of porous media, pellet diameter and combustor scale. The wave propagation velocity of inclinational flame is studied and compared with flat flame. The growth and reduction of inclinational instability are analysed at different conditions. The numerical results show that a development of inclinational instability causes essential flow non-uniformity and can result in a separation of the flame front in the multiple flame zones. The limited conductive and radiant heat transfer in the solid phase, small pellet diameter of packed bed, high inlet velocity, large combustor scale and low equivalence ratio promote the instability growth. The inclinational instability is suppressed in a reciprocal combustor.

12/00738 Operation strategy for multi-stage pyrolysis

Cheung, K.-Y. *et al. Journal of Analytical and Applied Pyrolysis*, 2011, 91, (1), 165–182.

Pyrolysis has been extensively studied in past decades as its potential to convert organic wastes into bio-fuels. Pyrolysis is an overall endothermic process but preformed exothermically at its early stage. The overall energy consumption as well as the product quality and yield are affected by the heating rate and the operation temperature. In order to reach its full potential to produce bio-fuels, the energy consumption of the process has to be minimized. An idea to reduce the pyrolysis energy consumption is observed, which suggests trapping the exothermic heat released in the beginning of the pyrolysis process and using it to fulfil the energy requirement of the endothermic reactions at the end of the process. To achieve this, the pyrolysis has to be performed in multiple stages. The operation strategy of the multi-stage pyrolysis, including the number of stages, the operating conditions (e.g. process temperature, heating rate) and residence times of each stages, have to be carefully designed to obtain the most energy saving and the best product yield. The operating strategy of a pyrolysis process therefore greatly depends on the pyrolysis kinetics and the control of heat transfers. Waste tyre pyrolysis is chosen as the study example in this paper. The corresponding reaction kinetics at different heating rates are investigated via experiments. Based on the experimental results, a mathematical model integrating kinetics and heat transfers is then developed. The objective of the model is to design a suitable operation strategy for the multi-stage pyrolysis process. A four-stage strategy is finally proposed for the tyre pyrolysis, which has the sequence of heating, adiabatic, heating and adiabatic. The strategy is verified by the model, and it is capable to save about 22.5% energy consumption compared to the conventional strategy.

12/00739 Pyrolysis gasification of dried sewage sludge in a combined screw and rotary kiln gasifier

Young, N. C. *et al. Applied Energy*, 2011, 88, (4), 1105–1112.

A pyrolysis gasifier, with carbonization and activation steps, was developed to convert dried sludge into activated char and gas fuel energy. To determine the optimal driving conditions, parametric investigations were conducted on the amount of steam input, pyrolysis gasifier temperature and moisture content in the dried sludge. The optimal conditions for the dried sludge were found to be a steam input of 10 mL/min, gasifier temperature of 820 °C and moisture content of 11% with a holding time in the pyrolysis gasifier of 1 h. The specific area of the activated char was 40.1 m^2/g, with an average pore diameter and volume of 63.49 Å and 0.2354 cm^3/g, respectively. The pyrolysis gases were H_2 (34.1%), CO (18.6%), CH_4 (8.5%) and CO_2 (8%). The higher heating value for the pyrolysis gas was 10,107 kJ/N m^3. To determine the tar adsorption characteristics, a benzene adsorption test was conducted using a fixed bed adsorption tower ($H/D = 2$, GHSV = 1175/h). The saturation point of the activated char was found after 45 min, and the amount of adsorption was 140 mg/g. Therefore, the pyrolysis gasification of sewage sludge can produce activated char which can be used to reduce tar, and gasification gas which can be utilized as a high enthalpy gas fuel.

12/00740 Pyrolysis of coal-tar asphaltene in supercritical water

Han, L. *et al. Journal of Analytical and Applied Pyrolysis*, 2011, 91, (2), 281–287.

Pyrolysis of coal-tar asphaltene, the main active component of coal tar in supercritical water (SCW), is investigated to further understand the upgrading mechanism of coal tar. It is found that coal-tar asphaltene converts to gas, maltene and char both in N_2 and in SCW, but the conversion of coal-tar asphaltene and the yield of maltene in SCW are significant higher than those in N_2. The effect of maltene and char in coal tar on the pyrolysis of coal-tar asphaltene is also studied. The results indicate that the presence of maltene could suppress the formation of char. And the addition of char could reduce the maltene yield. The analysis of pyrolysis product indicates the aromatic nucleus of asphaltene molecule is mainly composed of two to four rings aromatic hydrocarbons. Based on these results the pyrolysis mechanism of asphaltene in SCW was discussed.

12/00741 Real-time method for the identification and quantification of hydrocarbon pyrolysis products: part I. Development and validation of the infra red technique

Abraham, G. *et al. Journal of Analytical and Applied Pyrolysis*, 2011, 91, (2), 368–376.

Due to large heat load encountered in high-speed flight (over Mach 5), the regenerative cooling of the engine leads to the study of the endothermic pyrolysis of the onboard hydrocarbon fuel, which acts as a coolant. However the control and regulation of such a technology implies to have a correct knowledge of the endothermic pyrolysis of the onboard hydrocarbon fuel, which motivates the development of a quantitative measuring method adapted to in-flight applications. A Fourier transform infrared spectrometer is used and a specific method has been developed to identify and to quantify the major hydrocarbon products of the pyrolysis. The technique is validated and tested at the outlet of the experimental pyrolysis process which operates under steady-state conditions from 823 K to 1023 K and up to 60 bar. Two mass flow rates (0.05 and 0.1 g s^{-1}) are studied with titanium reactor to determine the limits of validity and to improve the method. Several synthetic and jet fuels have been tested (heptane, decane, dodecane and two kerosenes). The quantities of five light hydrocarbons (methane, ethane, ethylene, propane, propylene) are determined. The method, based on classical least square processing, is validated with respect to gas chromatograph (and mass spectrometer) analysis notably. A minimum molar fraction of 5 mol.% can be obtained and the accuracy is better than 2 mol.%.

12/00742 Real-time method for the identification and quantification of hydrocarbon pyrolysis products: part II. Application to transient pyrolysis and validation by numerical simulation

Gascoin, N. *et al. Journal of Analytical and Applied Pyrolysis*, 2011, 91, (2), 377–387.

A real-time quantification infrared method has been developed with a gas cell to determine the composition of hydrocarbon pyrolysis products. The aim is to chemically characterize the fuel decomposition in case of regenerative cooling. The method can be extended to a large variety of applications. A transient analysis of the method behaviour is conducted to estimate its capacity to be applied to unsteady conditions (one measure per second), which can be encountered in cooling activity and unsteady processes. A numerical tool called RESPIRE (French acronym for supersonic combustion ramjet cooling with endothermic fuel, transient reactor programming) is used to help in understanding the complex phenomena involved in such a chemical reactor. The

validation of transient behaviour with respect to the computations shows negligible time delay (less than a than few seconds with gasification rate higher than 60 wt%) due to residence time in the experimental setup. The quantification accuracy is confirmed to be around 2 mol%. The agreement obtained on gas cell measurements is found to be correct over 10–20 wt% of gasification rate and very satisfactory over 60 wt% but this depends on the species. An extension of the method has been developed with a dedicated online cell to be specifically applied to supercritical and multiphase flows. The quantification of the gas phase in the pyrolysis mixture in case of biphasic flow is proposed and validated with an uncertainty around 3 wt%. The coke formation is monitored as a function of time and its quantification is even tested with 50% of uncertainty after a numerical calibration with respect to simulation.

12/00743 Self-ignition combustion synthesis of $LaNi_5$ at different hydrogen pressures

Yasuda, N. *et al. International Journal of Hydrogen Energy*, 2011, 36, (14), 8604–8609.

This study describes the self-ignition combustion synthesis (SICS) of $LaNi_5$ utilizing the hydrogenation heat of metallic calcium at different hydrogen pressures, and focus on the effect of hydrogen pressure on the ignition temperature and the initial activation of hydrogenation. In the experiments, La_2O_3, Ni, and Ca were dry-mixed, and then heated at 0.1, 0.5, and 1.0 MPa of hydrogen pressure until ignition due to the hydrogenation of calcium. The products were recovered after natural cooling for 2 h. The results showed that the ignition temperature lowered with hydrogen pressure. The products changed from bulk to powder with hydrogen pressure. This was probably caused by volume expansion due to hydrogenation at higher pressure. The product obtained at 1.0 MPa showed the highest hydrogen storage capacity under an initial hydrogen pressure of 0.95 MPa. The results of this research can be applied as an innovative production route for $LaNi_5$ without the conventional melting of La and Ni.

12/00744 Study of inexpensive oxygen carriers for chemical looping combustion

Fossdal, A. *et al. International Journal of Greenhouse Gas Control*, 2011, 5, (3), 483–488.

Norwegian industrial tailings and by-products, as well as naturally occurring minerals and ores have been surveyed with the purpose of identifying candidate oxygen carrier materials for use in a chemical looping combustion process. Nine materials, based on manganese and/or iron oxide, were selected for an initial screening test; six were deemed promising and were hence investigated further. Thermogravimetric experiments were performed to investigate the oxygen capacity, the reaction kinetics and reversibility of the oxygen absorption reaction. A manganese ore with a reversible capacity of 4.9 wt% oxygen at 1000 °C was selected as the most promising for chemical looping combustion applications. This material was modified by addition of calcia to explore the possibility of enhancing the kinetic, catalytic and mechanical properties. The addition of excess calcium relative to manganese resulted in formation of calcium manganite and related phases. The oxygen capacity of the modified material was 4.5 wt% at 1000 °C, but it has potential advantages in terms of kinetics and chemical and mechanical stability relative to the pure ore.

12/00745 The investigations of temperature distributions in an opposed multi-burner gasifier

Yu, G.-S. *et al. Energy Conversion and Management*, 2011, 52, (5), 2235–2240.

In a bench-scale opposed multi-burner (OMB) gasifier, the temperatures of gasification chamber and quench chamber are measured by thermocouples, and the temperature distributions of flame sections are reconstructed by the Filtered back-projection method. The results show that the temperature of gasification chamber increases slowly as the inserted distance increases in both diesel and coal–water slurry (CWS) tests. The syngas temperature decreases rapidly when it passes through the inlet of quench chamber. The impinging flames of diesel or CWS gasification all focus on the gasifier centre due to restraining by each other, and can avoid scouring the refractory wall and prolong the lives of refractory. At the test conditions, the temperature distributions of diesel flames are 1650–2100 °C and those of CWS flames are 1500–2000 °C. The flame temperature distributions appear to be a typical simple peak. The investigations can provide some information for the industrial gasifier.

12/00746 Thermal performance of a meso-scale liquid-fuel combustor

Vijayan, V. and Gupta, A. K. *Applied Energy*, 2011, 88, (7), 2335–2343.

Combustion in small-scale devices poses significant challenges due to the quenching of reactions from wall heat losses as well as the significantly reduced time available for mixing and combustion. In the case of liquid fuels there are additional challenges related to atomization, vaporization and mixing with the oxidant in the very short time-scale liquid-fuel combustor. The liquid fuel employed here is methanol with air as the oxidizer. The combustor was designed based on the heat recirculating concept wherein the incoming reactants are preheated by the combustion products through heat exchange occurring via combustor walls. The combustor was fabricated from Zirconium phosphate, a ceramic with very low thermal conductivity ($0.8\,W\,m^{-1}\,K^{-1}$). The combustor had rectangular shaped double spiral geometry with combustion chamber in the centre of the spiral formed by inlet and exhaust channels. Methanol and air were introduced immediately upstream at inlet of the combustor. The preheated walls of the inlet channel also act as a pre-vaporizer for liquid fuel which vaporizes the liquid fuel and then mixes with air prior to the fuel–air mixture reaching the combustion chamber. Rapid pre-vaporization of the liquid fuel by the hot narrow channel walls eliminated the necessity for a fuel atomizer. Self-sustained combustion of methanol–air was achieved in a chamber volume as small as $32.6\,mm^3$. The results showed stable combustion under fuel-rich conditions. High reactant preheat temperatures (675–825 K) were obtained; however, the product temperatures measured at the exhaust were on the lower side (475–615 K). The estimated combustor heat load was in the range 50–280 W and maximum power density of about $8.5\,GW/m^3$. This is very high when compared to macro-scale combustors. Overall energy efficiency of the combustor was estimated to be in the range of 12–20%. This suggests further scope of improvements in fuel–air mixing and mixture preparation.

12/00747 Thermographic phosphors for thermometry: a survey of combustion applications

Aldén, M. *et al. Progress in Energy and Combustion Science*, 2011, 37, (4), 422–461.

Being able to measure temperature accurately in combustion and in fire-related applications is important for giving a better understanding of heat transfer phenomena and improving existing models. In this review paper a method based on the spectroscopy of inorganic luminescent materials is described and exemplified in experiments related to combustion. The method involves the use of thermographic phosphors which enable remote temperature diagnostics to be performed with a high degree of sensitivity and accuracy. The technique is superior to those based on thermocouples and pyrometry, particularly in the vicinity of flames and when the measured surface is subjected to random movements. Several phosphor materials suitable for temperature probing are described. The application of thermographic phosphors to temperature measurements in one-point and in two-dimensions in flame spread scenarios, and in pyrolysis experiments involving different construction materials and polymers are described. Many thermographic phosphors have the property of being insensitive to variations in pressure up to 1 GPa. This property extends the use and development of thermographic thermometry to other domains, such as internal combustion engines. The temperature has been measured in a point and in two-dimensions inside the combustion chamber. The complex procedures required to implement the use of thermocouples on moving objects inside an engine make thermocouples an expensive choice. It also limits the possibilities of altering the measurement locations and thereby also complicating the investigation of different engine geometries and components. Thermographic phosphors have also been employed in gas turbine applications. Temperature probing in the afterburner of a full-size aircraft engine is described with the aim to study the effects of various engine loads on the wall temperature. Furthermore, the application of thermographic phosphors to study the temperature of droplets in relation to sprays is described. In spray dynamics, temperature is a crucial parameter for gaining an understanding of atomization, evaporation and heat convection from the surrounding gases. Finally the application of thermographic phosphors for gas temperature measurement by seeding the particles into a gas flow is described together with the challenges associated with seeding the particles for *in situ* flame measurements.

12/00748 Transport properties for combustion modeling

Brown, N. J. *et al. Progress in Energy and Combustion Science*, 2011, 37, (5), 565–582.

This review examines current approximations and approaches that underlie the evaluation of transport properties for combustion modelling applications. Discussed in the review are: the intermolecular potential and its descriptive molecular parameters; various approaches to evaluating collision integrals; supporting data required for the evaluation of transport properties; commonly used computer programs for predicting transport properties; the quality of experimental measurements and their importance for validating or rejecting approximations to property estimation; the interpretation of corresponding states; combination rules that yield pair molecular potential parameters for unlike species from like species parameters; and mixture approximations. The insensitivity of transport properties to the intermolecular forces is noted, especially the non-uniqueness of the supporting potential parameters. Viscosity experiments of pure substances and binary mixtures measured post-1970 are used to

evaluate a number of approximations; the intermediate temperature range $1 < T^* < 10$, where T^* is kT/ε, is emphasized since this is where rich data sets are available. When suitable potential parameters are used, errors in transport property predictions for pure non-polar substances and their binary mixtures are less than 5% when they are calculated using the approaches of earlier studies. Recommendations stemming from the review include: (1) revisiting the supporting data required by the various computational approaches, and updating the data sets with accurate potential parameters, dipole moments, and polarizabilities; (2) characterizing the range of parameter space over which the fit to experimental data is good, rather than the current practice of reporting only the parameter set that best fits the data; (3) looking for improved combining rules, since existing rules were found to under-predict the viscosity of mixtures in most cases; (4) performing more transport property measurements for mixtures that include radical species, an important but neglected area; (5) using the TRANLIB approach for treating polar molecules; (6) continuing to evaluate whether a different parameterization is required for the intermolecular potential for $T^* > 10$; (7) performing more accurate measurements of the molecular parameters used to evaluate the molecular heat capacity and the rotational relaxation collision number, since they affect thermal conductivity; and (8) using the EGLIB approach and computer program with improved supporting data to evaluate transport properties. EGLIB uses the TRANLIB methodology for collision integral evaluation.

12/00749 Turbulence effects on evaporation rate-controlled spray combustor performance

Labowsky, M. *et al. International Journal of Heat and Mass Transfer*, 2011, 54, (11–12), 2683–2695.

This paper considers the effects of gas-phase turbulence on the evaporation dynamics of a polydispersed dilute fuel spray in an adiabatic well-stirred reactor (WSR) supplied with hot compressed air. Turbulence increases the time-averaged rate of heat diffusion-controlled droplet evaporation but the augmentation factor is droplet size-dependent because of droplet inertia and evaporative drag reduction. Consequently, each droplet in a spray population will not be characterized by the same rate of area change even in the same time-averaged environment. When these physical phenomena are convoluted with the residence time distribution characterizing a WSR (simulating, say, the primary zone of an aircraft gas turbine combustor), the authors predict the resulting fraction evaporated, evaporation rate-controlled combustion 'intensity', and corresponding exit droplet size distributions (DSD).

Fire safety

12/00750 Experimental study on the hazards of the jet diffusion flame of liquefied dimethyl ether

Mogi, T. *et al. Fuel*, 2011, 90, (7), 2508–2513.

Dimethyl ether (DME) has been considered as a substitute for diesel fuel because it has a low auto-ignition temperature and produces less NO_x, SO_x, and particulate matter. However, the introduction of DME vehicles needs widely available DME supply stations. Moreover, the preparation of safety regulations for DME supply stations is very important, and so safety data is needed. Therefore, the present paper reports the hazards of the DME jet diffusion flame, which is one of several hazardous properties of DME, by studying the results of leaking gas and liquid DME. DME jets were released horizontally from circular nozzles whose diameters were 0.2, 0.4, 0.8 and 2 mm, and the release pressure was varied from the saturated vapour pressure to 2 MPa. When gaseous DME was released at the saturated vapour pressure, the flame was blown out. However, when liquefied DME was released, the flame formed. The authors obtained the experimental equations for estimating the scale and thermal hazards of DME diffusion flames.

12/00751 Exploratory studies of modeling approaches for hydrogen triple flames

Owston, R. and Abraham, J. *International Journal of Hydrogen Energy*, 2011, 36, (14), 8570–8582.

A review of triple flame modelling is first presented, which demonstrates the need for additional work in this area. Building on previous methods described in the literature, a hybrid model that uses a weighted average of one-dimensional premixed and diffusion flamelet reaction rates has been proposed and evaluated for a hydrogen triple flame. Results indicated that some type of progress variable is needed for application of the diffusion flamelet contribution. Weighting the premixed flamelet reaction rate contribution at 100%, it is shown that peak temperatures between the model and a case employing detailed chemistry vary 7.5%, while heat release rate, flame speed, and mass fraction contours agree well. A second model, based on a library of reaction rates built from numerical studies which directly resolve the propagating triple flame has also been tested. Computational time for the baseline case is shown to be reduced by a factor of 3.5 in comparison to use of detailed chemistry. The role of scalar dissipation rate as a necessary independent variable to the library has also been investigated using simulations with variable mixing layer thicknesses. Overall, it is found that large changes in local mixture fraction gradient cause rather small changes in propagation speed and total heat release rate of the hydrogen triple flame. This implies that such a model may be useful for CFD simulations that do not employ spatial resolution capable of resolving the triple flame itself.

12/00752 Fire debris analysis by Raman spectroscopy and chemometrics

González-Rodríguez, J. *et al. Journal of Analytical and Applied Pyrolysis*, 2011, 91, (1), 210–218.

A paper reporting the use of Raman spectroscopy in fire debris analysis is presented. Five polymer based samples, namely carpet (polypropylene), nylon stockings (nylon), foam packaging (polystyrene), CD cases (polystyrene) and DVD cases (polypropylene) were burnt with each one of the following ignitable liquids: petrol, diesel, kerosene and ethanol. Raman shifts were obtained and, in some cases, peaks were identified to correspond to pyrolysis products in the form of alkanes, aromatic or polyaromatic compounds. All pyrolysis peaks were used to produce a principal component analysis of the burned samples with the different ignitable liquids. The change in the Raman spectra made it possible to identify some of the pyrolysis products produced in the combustion and also to identify the different plastic materials in fire debris, even when different fuels have been used and the chemical and structural identity of the plastic has been altered in the fire.

12/00753 Magnetometer measurements to characterize a subsurface coal fire

Ide, T. S. *et al. International Journal of Coal Geology*, 2011, 87, (3–4), 190–196.

Underground coal fires pose a threat to the environment and the health of those living in their proximity and can result in economic losses if these fires occur at mining areas. Design of methods to extinguish these fires requires that the extent of the subsurface fire be delineated. A conceptual picture of the workings of a subsurface coal fire near Durango, CO is presented first, which shows how the overburden above the burning coal seam can become heated. In high temperature and low O_2 conditions, the heating of the overburden leads to the formation of magnetite, and its presence and the alignment of magnetic moments can be detected by a magnetometer. Magnetometer surveys allow high resolution areal mapping that differentiates among previously burned, currently burning, and unburned coal seam areas. The current and previous locations of the subsurface fire regions that are delineated by the magnetometer survey conducted at a fire on the Southern Ute Indian Reservation are consistent with various supporting data such as gas composition, temperature, and snowmelt data.

12/00754 Spark spread – a screening parameter for combined heating and power systems

Smith, A. D. *et al. Applied Energy*, 2011, 88, (5), 1494–1499.

Combined heating and power (CHP) systems may be considered for installation if they produce savings over conventional systems with separate heating and power. For a CHP system with a natural gas engine as the prime mover, the difference between the price of natural gas and the price of purchased electricity, called spark spread, is an indicator as to whether a CHP system might be considered or not. The objective of this paper is to develop a detailed model, based on the spark spread, that compares the electrical energy and heat energy produced by a CHP system against the same amounts of energy produced by a traditional, or separate heating and power (SHP) system that purchases electricity from the grid. An expression for the spark spread based on the cost of the fuel and some of the CHP system efficiencies is presented in this paper as well as an expression for the payback period for a given capital cost and spark spread. The developed expressions allow determining the required spark spread for a CHP system to produce a net operational savings over the SHP in terms of the performance of system components. Results indicate that the spark spread which might indicate favourable payback varies based on the efficiencies of the CHP system components and the desired payback period. In addition, a new expression for calculating the payback period for a CHP system based on the CHP system capital cost per unit of power output and fuel cost is proposed.

09 PROCESS HEATING, POWER AND INCINERATION

Energy applications in industry

12/00755 An integrated power generation system combining solid oxide fuel cell and oxy-fuel combustion for high performance and CO_2 capture

Park, S. K. *et al. Applied Energy*, 2011, 88, (4), 1187–1196.

An integrated power generation system combining solid oxide fuel cell (SOFC) and oxy-fuel combustion technology is proposed. The system is revised from a pressurized SOFC-gas turbine hybrid system to capture CO_2 almost completely while maintaining high efficiency. The system consists of SOFC, gas turbine, oxy-combustion bottoming cycle, and CO_2 capture and compression process. An ion transport membrane (ITM) is used to separate oxygen from the cathode exit air. The fuel cell operates at an elevated pressure to facilitate the use of the ITM, which requires high pressure and temperature. The remaining fuel at the SOFC anode exit is completely burned with oxygen at the oxy-combustor. Almost all of the CO_2 generated during the reforming process of the SOFC and at the oxy-fuel combustor is extracted from the condenser of the oxy-combustion cycle. The oxygen-depleted high pressure air from the SOFC cathode expands at the gas turbine. Therefore, the expander of the oxy-combustion cycle and the gas turbine provides additional power output. The two major design variables (steam expander inlet temperature and condenser pressure) of the oxy-fuel combustion system are determined through parametric analysis. There exists an optimal condenser pressure (below atmospheric pressure) in terms of global energy efficiency considering both the system power output and CO_2 compression power consumption. It was shown that the integrated system can be designed to have almost equivalent system efficiency as the simple SOFC-gas turbine hybrid system. With the voltage of 0.752 V at the SOFC operating at 900 °C and 8 bar, system efficiency over 69.2% is predicted. Efficiency penalty due to the CO_2 capture and compression up to 150 bar is around 6.1%.

12/00756 CFD simulation and experimental study for two-phase flow through the trickle bed reactors, sock and dense loaded by trilobe catalysts

Bazmi, M. *et al. International Communications in Heat and Mass Transfer*, 2011, 38, (3), 391–397.

In this study single and two-phase flow through trickle bed reactors loaded with two different loading manners, sock and dense, have been investigated numerically and experimentally. The CT-scan imaging and an image processing code have been used to investigate radial porosity distribution of trilobe catalysts in sock and dense loading procedures in trickle bed reactors and two different correlations have been proposed. These correlations were used in a single and two phase CFD code for prediction of pressure drop of gas flow in dry and prewet trilobe catalyst packed bed and also pressure drop and dynamic liquid holdup for two phase flow. In addition, these variables were studied experimentally with a laboratory scale trickle bed reactor. The results of CFD simulations show a very good agreement with experimental data.

12/00757 Characterization of a limestone in a batch fluidized bed reactor for sulfur retention under oxy-fuel operating conditions

de Diego, L. F. *et al. International Journal of Greenhouse Gas Control*, 2011, 5, (5), 1190–1198.

CO_2 and SO_2 are some of the main polluting gases emitted into atmosphere in combustion processes using fossil fuel for energy production. The former is one of the major contributors to build-up the greenhouse effect implicated in global climate change and the latter produces acid rain. Oxy-fuel combustion is a technology, which burns fuel with a mix of pure O_2 and recirculated CO_2. With this technology, the CO_2 concentration in the flue gas may be enriched by up to 95%, allowing easy CO_2 recovery. In addition, oxy-fuel combustion in fluidized beds allows *in situ* desulfurization of combustion gases by supplying a calcium-based sorbent. In this work, the effect of the principal operation variables affecting the sulfation reaction rate in fluidized bed reactors (temperature, CO_2 partial pressure, SO_2 concentration and particle size) under typical oxy-fuel combustion conditions have been analysed in a batch fluidized bed reactor using a limestone as the sorbent. It has been observed that sulfur retention can be carried out by direct sulfation of the $CaCO_3$ or by sulfation of the CaO (indirect sulfation) formed by $CaCO_3$ calcination. Direct sulfation and indirect sulfation operating conditions depended on the temperature and CO_2 partial pressure. The rate of direct sulfation rose with temperature and the rate of indirect sulfation for long reaction times decreased with temperature. An increase in the CO_2 partial pressure had a negative influence on the sulfation conversion reached by the limestone due to a higher temperature was needed to work in conditions of indirect sulfation. Thus, it is expected that the optimum temperature for sulfur retention in oxy-fuel combustion in fluidized bed reactors be about 925–950 °C. Sulfation reaction rate rose with decreasing sorbent particle size and increasing SO_2 concentration.

12/00758 Coal pyrolysis in a fluidized bed reactor simulating the process conditions of coal topping in CFB boiler

Zhang, X. *et al. Journal of Analytical and Applied Pyrolysis*, 2011, 91, (1), 241–250.

Simulating the conditions of pyrolytic topping in a fluidized bed reactor integrated into a CFB boiler, the study was devoted to the reaction fundamentals of coal pyrolysis in terms of the production characteristics of pyrolysis oil in fluidized bed reactors, including pyrolysis oil yield, required reaction time and the chemical species presented in the pyrolysis oil. The results demonstrated that the maximal pyrolysis oil yield occurred on conditions of 873 K, with a reaction time of 3 min and in a reaction atmosphere gas simulating the composition of pyrolysis gas. Adding H_2 and CO_2 into the reaction atmosphere decreased the pyrolysis oil yield, while the oil yield increased with increasing the CO and CH_4 contents in the atmosphere. TG-FTIR analysis was conducted to reveal the effects of reaction atmosphere on the chemical species present in the pyrolysis oil. The results clarified that the pyrolysis oil yield reached its maximum when the simulated pyrolysis gas was the reaction atmosphere, but there were slightly fewer volatile matters in the pyrolysis oil than the oil generated in the N_2 atmosphere. All of these results are expected not only to reveal the composition characteristics of the pyrolysis oil from different conditions of the coal topping process but also to optimize the pyrolysis conditions in terms of maximizing the light pyrolysis oil yield and quality.

12/00759 Conceptual design of a three fluidised beds combustion system capturing CO_2 with CaO

Martínez, I. *et al. International Journal of Greenhouse Gas Control*, 2011, 5, (3), 498–504.

In this work, the Aspen Hysys conceptual design of a new process for energy generation at large scale with implicit CO_2 capture is presented. This process makes use of the CaO capability for CO_2 capture at high temperature and the possibility of regenerating this sorbent working in interconnected fluidized bed reactors operating at different temperatures. The proposed process has the advantage of producing power with minimum CO_2 emissions and very low energy penalties compared with similar air-based combustion power plants. In this system, five main parts can be distinguished: the combustor where coal is burnt with air, the calciner where the fresh and the recycled $CaCO_3$ is calcined, the carbonator where the CO_2 produced in the combustor is captured, the supercritical steam cycle and the CO_2 compression system. In this arrangement, the three fluidized bed reactors are interconnected in such a way that it is possible to perform the $CaCO_3$ calcination at a temperature of 950 °C with the energy transported by a hot solid stream produced in the circulating fluidized bed combustor operating at 1030 °C. The stream rich in CaO produced in the calciner is split into three parts. One of them is transported to the carbonator operating at 650 °C where most of the CO_2 in the flue gas produced in the combustor is captured. The second one is sent to the combustor, where it is heated up and used as energy carrier. The third solid stream that leaves the calciner is a purge in order to maintain the capture system activity and to avoid inert material accumulation. Because of the high temperatures involved in all the system, it is possible to recover most of the energy in the fuel and to produce power in a supercritical steam cycle. A case study is presented and it is demonstrated that under these operating conditions, 90% CO_2 capture efficiency can be achieved with no energy penalty further than the one originated in the CO_2 compression system.

12/00760 Derivation of correlations to evaluate the impact of retrofitted post-combustion CO_2 capture processes on steam power plant performance

Liebenthal, U. *et al. International Journal of Greenhouse Gas Control*, 2011, 5, (5), 1232–1239.

When integrating a post-combustion CO_2 capture process and CO_2 compression into a steam power plant, the three interface quantities heat, electricity and cooling duty must be satisfied by the power plant, leading to a loss in net efficiency. The heat duty shows to be the largest contributor to the overall net efficiency penalty of the power plant. Additional energy penalty results from the cooling and electric power duty of the capture and compression units. In this work, the dependency of the energy penalty on the quantity and quality of the heat duty is analysed and quantified for a state-of-the-art hard coal

fired power plant. Furthermore, the energy penalty attributed to the additional cooling and power duty is quantified. As a result correlations are provided which enable to predict the impact of the heat, cooling and electricity duty of post-combustion CO_2 capture processes on the net output of a steam power plant in a holistic approach.

12/00761 Design study of a 150 kW_{th} double loop circulating fluidized bed reactor system for chemical looping combustion with focus on industrial applicability and pressurization

Bischi, A. *et al. International Journal of Greenhouse Gas Control*, 2011, 5, (3), 467–474.

Nowadays the laboratory-scale feasibility of the chemical looping combustion technology has been proved. This article deals with many of the design requirements that need to be fulfilled to make this technology applicable at industrial scale. A design for a 150 kW_{th} chemical looping combustion reactor system is proposed. In the base case it is supposed to work with gaseous fuels and inexpensive oxygen carriers derived from industrial by-products or natural minerals. More specifically the fuel will be methane and a manganese ore will be the basis for the oxygen carrier. It is a double loop circulating fluidized bed where both the air reactor and the fuel reactor are capable to work in the fast fluidization regime in order to increase the gas solids contact along the reactor body. High operational flexibility is aimed, in this way it will be possible to run with different fuels and oxygen carriers as well as different operating conditions such as variation in air excess. Compactness is a major goal in order to reduce the required solid material and possibly to enclose the reactor body into a pressurized vessel to investigate the chemical looping combustion under pressurized conditions. The mass and heat balance are described, as well as the hydrodynamic investigations performed. Most design solutions presented are taken from industrial standards as one main objective is to meet commercial requirements.

12/00762 Development of novel absorbents for CO_2 capture from blast furnace gas

Goto, K. *et al. International Journal of Greenhouse Gas Control*, 2011, 5, (5), 1214–1219.

In order to establish energy-saving technology for CO_2 capture from blast furnace gas, novel absorbents were developed in the laboratory and evaluated at a 1 t_{CO2}/d test plant. At first, CO_2 absorption and desorption behaviours of single-component amine solvents for simulated blast furnace gas (CO_2/N_2 = 20%/80%) were investigated through a screening test using a small scrubbing bottle. These amine solvents were additionally analysed using nuclear magnetic resonance (^{13}C NMR) spectroscopy and reaction calorimetry. The results of the laboratory experiments showed that there was a trade-off between absorption rate and enthalpy of absorption but some absorbents had unique features. For example, 2-isopropylaminoethanol (IPAE) had high absorption rate and small enthalpy of absorption. Then, new IPAE-based amine solvents (RITE solvents: RITE-A and RITE-B) were formulated and evaluated at the 1 t_{CO2}/d test plant. CO_2 regeneration energies of the RITE solvents were 3.3 and 3.1 GJ/t_{CO2}, respectively. With certain process conditions and plant specifications optimized, RITE-B was estimated to have the potential to achieve 2.5 GJ/t_{CO2}.

12/00763 Eco-efficiency of the world cement industry: a data envelopment analysis

Oggioni, G. *et al. Energy Policy*, 2011, 39, (5), 2842–2854.

Chemical reactions and the combustion of dirty fuels, such as coal and petroleum coke (petcoke), that are used in cement production processes generate a significant amount of CO_2 emissions. This paper provides an eco-efficiency measure for 21 prototypes of cement industries operating in many countries by applying both a data envelopment analysis (DEA) and a directional distance function approach, which are particularly suitable for models where several production inputs and desirable and undesirable outputs are taken into account. To understand whether this eco-efficiency is due to a rational utilization of inputs or to a real carbon dioxide reduction as a consequence of environmental regulation, the cases are analysed where CO_2 emissions can either be considered as an input or as an undesirable output. Empirical results show that countries where cement industries invest in technologically advanced kilns and adopt alternative fuels and raw materials in their production processes are eco-efficient. This gives a comparative advantage to emerging countries, such as India and China, which are incentivized to modernize their production processes.

12/00764 Energy efficiency improvements through surveillance applications in industrial buildings

Silvestre-Blanes, J. and Pérez-Lloréns, R. *Energy and Buildings*, 2011, 43, (6), 1334–1340.

Presence sensors for energy control based on classic technologies to detect movement are now commonly seen in many areas of life. However, their use in structurally complex environments is not very common, due to their lack of reliability in these types of situations. Falling prices in technologies associated with surveillance applications are leading to a huge increase in their use in all types of environment, with monitoring of traffic and people the most common of these. This study analysed occupancy patterns in manufacturing industries with the aim of determining the possible energy savings that could be obtained using these new technologies. The authors also carried out an analysis of the possibilities of using these technologies as presence sensors, analysing the trends and limitations associated with them.

12/00765 Energy flow analysis in pulp and paper industry

Hong, G.-B. *et al. Energy*, 2011, 36, (5), 3063–3068.

This work analysed the energy flow of the pulp and paper industry in Taiwan. The potential technology options that were examined focus on how to capture some of the energy currently lost in the processes and then identifying the areas with energy-saving potential that could also have large impacts across a variety of industries. In addition, the energy-saving potential of these options was evaluated. The energy-saving potential of the pulp and paper industry would be around 6939.9 KLOE/M. The greatest energy-saving potential lies with improving energy distribution and equipment efficiency, which would together potentially comprise 86.8% of total energy conservation. This analysis can serve as a benchmark for current pulp and paper making operations, and as a base case for stimulating changes toward more efficient energy utilization in the pulp and paper industry.

12/00766 Exergy-based indicators to evaluate the possibilities to reduce fuel consumption in lime production

Gutiérrez, A. S. and Vandecasteele, C. *Energy*, 2011, 36, (5), 2820–2827.

A new way to evaluate the energetic performance of lime shaft kilns is proposed. Two new exergy-based indicators are introduced for the evaluation, one to assess the exergy efficiency of limekilns and the other indicator to assess the effectiveness of the exergy consumption of the dissociation reaction. The combination of both indicators provides a clear picture of the energetic performance of the process, highlighting the main potentialities for fuel saving (fuel consumption represents about 50% of total production costs). The validity of the proposed assessment is examined using some operating data measured in a commercial lime factory. Results show that introduction of exergy-based indicators in the assessment improves the evaluation of the energy consumption of the calcination process. In this way the impact of the process losses in the fuel consumption is better addressed.

12/00767 Heat transfer in gas–solid fluidized bed with various heater inclinations

Abid, B. A. *et al. International Journal of Heat and Mass Transfer*, 2011, 54, (9–10), 2228–2233.

The study explored the heat transfer properties in an air-fluidized bed of sand, heated with an immersed heat transfer tube positioned at several angles of inclination. Operating with fluidizing velocity up to 0.5 m/s; and particles of 150–350 μm diameter, the effect of air velocity and particle size on the average and maximum achieved heat transfer coefficient was examined for the heat transfer tube at angles of inclination in the range 0–90°. Experimental results showed that the angle of inclination altered the bubble size and behaviour close to the heat transfer tube hence the expected heat transfer coefficient, with the influence of tube inclination being less pronounced for smaller particles. The optimum angle of inclination was in the range of 10–15° relative to the direction of the flow, while the heat transfer coefficient had its lowest values at the angle of 45°, and thereafter improved upon transition to 90°. Upon comparison with existing correlations, a correction factor is proposed to account for the impact of the angle of inclination on the heat transfer coefficient calculated by the Molerus–Wirth semi-empirical correlation.

12/00768 Improving the environmental performance of biofuels with industrial symbiosis

Martin, M. and Eklund, M. *Biomass and Bioenergy*, 2011, 35, (5), 1747–1755.

In the production of biofuels for transport many critics have argued about the poor energy efficiency and environmental performance of the production industries. Optimism is thus set on the production of second generation biofuels, while first generation biofuels continue to dominate worldwide. Therefore it is interesting to consider how the environmental performance of first generation biofuel industries can be improved. The field of industrial symbiosis offers many possibilities for potential improvements in the biofuel industry and theories from this research field are used in this paper to highlight how environmental performance improvements can be accomplished. This comes in the form of by-product synergies and utility synergies which can improve material and energy handling. Furthermore, the processes and

products can gain increased environmental performance improvements by the adaption of a renewable energy system that will act as a utility provider for many industries in a symbiotic network. By-products may thereafter be upcycled through biogas production processes to generate both energy and a bio-fertilizer. A case study of an actual biofuel industrial symbiosis is also reviewed to provide support for these theories.

12/00769 Industrial combined heat and power (CHP) planning: development of a methodology and application in Greece

Salta, M. *et al. Applied Energy*, 2011, 88, (5), 1519–1531.

This paper establishes a methodology for the estimation of the primary energy savings of an industrial (sub)-sector and the primary energy savings of the total energy system due to CHP. A primary energy savings indicator within a (sub)-sector and a total primary energy savings indicator are developed which are related with the actual energy use of a (sub)-sector and the way of disposal of the excess CHP energy produced. The methodology is applied in an industrial sub-sector in Greece according to the 'power match' and the 'thermal match' CHP sizing scenarios; subsequently results are presented and the developed indicators are fully explained. It was found that the primary energy savings indicator of a sub-sector is determined by the efficiencies of the relevant technologies, and the interrelation of the 'power to heat' ratio of the CHP technology used and the 'power to heat' ratio of the sub-sector examined; the total primary energy savings indicator is determined by the efficiencies of the relevant technologies and the percentage of the CHP energy exported from the sub-sector. The methodology can be utilized for optimum CHP planning.

12/00770 Industrial relocation and energy consumption: evidence from China

Zhao, X. and Yin, H. *Energy Policy*, 2011, 39, (5), 2944–2956.

With economic development and the change of industrial structure, industrial relocation is an inevitable trend. In the process of industrial relocation, environmental externality and social cost could occur due to market failure and government failure. Little attention has been paid to this issue. This paper addresses this with a theoretical analysis and an empirical investigation on the relationship between China's industrial relocation in the early 1990s and energy consumption which is the primary source of CO_2 emission, an environmental externality that causes increasing concerns. The macro-policy analysis suggests that there would be a positive link between China's industrial relocation in the early 1990s and energy saving (and environmental externalities reduction). Using fixed-effect regression model and simulation method, an empirical support is added to this argument. In order to further reduce environmental externalities and social cost in the process of industrial relocation, policy suggestions are as follows: first, strengthen the evaluation of environmental benefits/costs; second, pay more attention to the coordinated social-economic development; third, avoid long-lived investment in high-carbon infrastructure in areas with industries moved in; fourth, address employment issue in the areas with industries moved out.

12/00771 Modeling and experimental studies on single particle coal devolatilization and residual char combustion in fluidized bed

Sadhukhan, A. K. *et al. Fuel*, 2011, 90, (6), 2132–2141.

Single particle devolatilization followed by combustion of the residual coal char particle has been analysed in a batch-fluidized bed. The kinetic scheme with distributed activation energy is used for coal devolatilization while multiple chemical reactions with volume reaction mechanism are considered for residual char combustion. Both the models couple kinetics with heat transfer. Finite volume method (FVM) is employed to solve fully transient partial differential equations coupled with reaction kinetics. The devolatilization model is used to predict the devolatilization time along with residual mass and particle temperature, while the combined devolatilization and char combustion model is used to predict the overall mass loss and temperature profile of coal. The computed results are compared with the experimental results of the present authors for combustion of Indian sub-bituminous coal (15% ash) in a fluidized bed combustor as well as with published experimental results for coal with low ash high volatile matter. The effects of various operating parameters like bed temperature, oxygen mole fraction in bulk phase on devolatilization time and burn-out time of coal particle in bubbling fluidized bed have been examined through simulation.

12/00772 Numerical study on NO_x/CO emissions in the diffusion flames of high-temperature off-gas of steelmaking converter

Li, S. *et al. Applied Energy*, 2011, 88, (4), 1113–1119.

The combustion of high-temperature off-gas of steelmaking converter with periodical change of temperature and CO concentration always leads to CO and NO_x over-standard emissions. In the paper, high-temperature off-gas combustion is simulated by adopting counterflow diffusion flame model, and some influencing factors of CO and NO_x emissions are investigated by adopting a detailed chemistry GRI 3.0 mechanism. The emission index of NO_x ($EINO_x$) decreases 1.7–4.6% when air stoichiometric ratio (SR) increase from 0.6 to 1.4, and it dramatically increases with off-gas temperature at a given SR when the off-gas temperature is above 1500 K. High-concentration CO in off-gas can result in high NO_x emissions, and NO_x levels increase dramatically with CO concentration when off-gas temperature is above 1700 K. Both SR and off-gas temperature are important for the increase of CO burnout index (BI_{CO}) when SR is less than 1.0, but BI_{CO} increase about 1% when off-gas temperature increases from 1100 K to 1900 K at SR > 1.0. BI_{CO} increases with CO concentration in off-gas, and the influence of off-gas temperature on BI_{CO} is marginal. BI_{CO} increases with the relative humidity (RH) in air supplied, but it increases about 0.5% when RH is larger than 30%.

12/00773 Prospective on the energy efficiency and CO_2 emissions in the EU cement industry

Pardo, P. *et al. Energy*, 2011, 36, (5), 3244–3254.

The cement industry is the third largest carbon-emitting industrial sector in the European Union. The present work analyses the potential for improvement in the energy efficiency and CO_2 emission reduction for this sector up to 2030. Three scenarios are analysed: baseline scenario (BS) representing the current evolution of the cement sector and two alternative scenarios (AS1 and AS2) studying respectively the sensitivity of fuel prices and CO_2 emission prices. The results for the BS show an improvement in the thermal energy efficiency and the CO_2 emissions per tonne of clinker, respectively, of 11% and 3.7% in 2030 compared with the level of 2002. However, for AS1 and AS2, these scenarios are insensitive to fuel and CO_2 emission prices, respectively. This can be explained by the fact that a large number of retrofits are economically feasible in the BS, leading to a significant reduction in the thermal energy consumption.

12/00774 Pyrolysis of meat-meal and bone-meal blends in a mechanically fluidized reactor

Cascarosa, E. *et al. Journal of Analytical and Applied Pyrolysis*, 2011, 91, (2), 359–367.

Nowadays, meat and bone meal produced in animal slaughterhouses and farms has become an important waste. Landfilling this residue means that its energy is lost. The pyrolysis of meat and bone meal produces a solid fraction which can be used as a fuel or as solid adsorbent, a liquid fraction with possible chemical applications and a low heating value gas. In this work, meat and bone meal has been pyrolysed with a new technology, a mechanically fluidized reactor (MFR). This MFR is a stainless steel cylinder with 7.7 cm i.d., and an internal height of 15.6 cm. The meat and bone meal pyrolysis was carried out at 500 °C of temperature. The effect of several factors (mixer speed, heating rate and feed composition) on the product yields, bio-oil phases yield, bio-oil heating value and char heating value was studied. The amount of pure meat meal in the feed had a strong impact on product yields and compositions. The liquid yield, which has two phases, varies from 22 to 52 wt% when the raw material fed changed from pure bone meal to pure meat meal.

12/00775 Simulation of circulating fluidized bed combustors firing indigenous lignite

Selcuk, N. and Ozkan, M. *International Journal of Thermal Sciences*, 2011, 50, (6), 1109–1115.

A comprehensive model, previously developed for a rectangular parallelepiped shaped 0.3 MW_t circulating fluidized bed combustor (CFBC) fired with high calorific value coal burning in sand and validated against experimental data is adapted to cylindrical configuration and is extended to incorporate NO_x formation and reduction reactions and pressure drops around cyclone, downcomer and loop seal. Its predictive accuracy is tested by applying it to the simulation of Middle East Technical University (METU) 150 kW_t CFBC burning low calorific value indigenous lignite with high volatile matter/fixed carbon (VM/FC) ratio in its own ash and comparing its predictions with measurements. Favourable comparisons are obtained between the predicted and measured temperatures and pressure profiles and emissions of gaseous species. Results reveal that predictive accuracy in pressure profile strongly depends on the correlation utilized for entrainment in dilute zone and that accuracy in NO emission requires data on partitioning of coal nitrogen into char-N and volatile-N and is affected significantly by dilute zone oxygen content.

12/00776 Systematic characterization of a PBI/H_3PO_4 sol–gel membrane – modeling and simulation

Siegel, C. *et al. Journal of Power Sources*, 2011, 196, (5), 2735–2749.

This work presents a three-dimensional, steady-state, non-isothermal model of a high-temperature polymer-electrolyte-membrane fuel cell (HTPEMFC) using a phosphoric acid-doped polybenzimidazole (PBI/H_3PO_4) sol–gel membrane. The model accounts for the gold-plated

copper current collector plates, the bipolar plates, all gas flow channels (flow-field), the gas diffusion layers, the reaction layers, and the membrane. Electrochemical reactions are modelled using an agglomerate approach and include the gas diffusivity and the gas solubility. The conductivity of the membrane is modelled using the Arrhenius equation to describe the temperature dependence. Finite elements are used to discretize all computational subdomains, and a commercially available code is used to solve the problem. The predicted values are compared to typical operating conditions, and a good agreement is found. The current density, the solid- and fluid-(gas)-phase temperatures and other quantities are analysed throughout the computational subdomains. It was observed that the Arrhenius approach is valid in a certain temperature range and may overpredict the PBI/H_3PO_4 sol–gel membrane conductivity at higher solid-phase temperatures. Moreover, it is shown how the fluid-(gas)-phase temperature influences the solid-phase temperature and the current density distribution. Concrete values are deduced from the simulations and discussed according to experimental test.

12/00777 The effect of increasing exports on industrial energy intensity in China

Zheng, Y. *et al. Energy Policy*, 2011, 39, (5), 2688–2698.

Given China's heavy reliance on fuel energy and the dominance of its industrial sector in the economy, improving energy efficiency remains one of the practical means for the country to decrease energy intensity and to fulfil its commitment made at the Copenhagen Climate Change Conference to achieve a 40–45% reduction in CO_2 emission intensity by 2020. This study investigates the impact of exports on industrial energy intensity to explore the possibility of reducing energy intensity through greater exports. A panel varying-coefficient regression model with a dataset of China's 20 industrial sub-sectors over 1999–2007 suggests that in general, greater exports aggravate energy intensity of the industrial sector and that great divergences exist in the impact of exports on energy intensity across sub-sectors. A panel threshold model further estimates the thresholds for the major determinants of energy intensity: exports, input in technological innovations, and foreign direct investment intensity. Given the great differences in specific sub-sector characteristics and the changing roles played by different factors across sub-sectors, there is no general export policy that would work for all sub-sectors in reducing sub-sector energy intensity. Instead, policies and measures aiming to encourage more efficient use of energy should take into full consideration the characteristics and situations of individual sub-sectors.

12/00778 Thermodynamic analysis and thermoeconomic optimization of a dual pressure combined cycle power plant with a supplementary firing unit

Ahmadi, P. and Dincer, I. *Energy Conversion and Management*, 2011, 52, (5), 2296–2308.

In this paper, a combined cycle power plant (CCPP) with a supplementary firing system is first thermodynamically analysed through energy and exergy. The optimal design of operating parameters of the plant is then performed by defining an objective function and applying a generic algorithm (GA) type optimization method. In order to optimally find the design parameters, a thermoeconomic method is employed. An objective function representing the total cost of the plant in terms of dollar per second is defined as the sum of the operating cost related to the fuel consumption and the capital investment for equipment purchase and maintenance costs. Subsequently, different parts of the objective function are expressed in terms of decision variables. Finally, the optimal values of decision variables are obtained by minimizing the objective function using a GA. Moreover, the influences of changes in the demanded power and fuel cost are studied by considering three different output powers (i.e. 160, 180 and 200 MW). To validate the present model, the results of the present simulation code are compared with the actual data. The results show that the average difference between the model results and the actual data is about 1.41%. Moreover, various cases are investigated to determine how to decrease the objective function (cost, mass flowrate, etc.) for the optimized design and operating parameters (fuel cost, power output, etc.).

10 SPACE HEATING AND COOLING/HEAT PUMPS

12/00779 A comparison of flow characteristics of refrigerants flowing through adiabatic straight and helical capillary tubes

Chingulpitak, S. and Wongwises, S. *International Communications in Heat and Mass Transfer*, 2011, 38, (3), 398–404.

This paper presents a numerical investigation of the flow characteristics of helical capillary tubes compared with straight capillary tubes. The homogenous two-phase flow model developed is based on the conservation of mass, energy, and momentum of the fluids in the capillary tube. This model is validated by comparing it with the experimental data of both straight and helical capillary tubes. Comparisons of the predicted results between the straight and helical capillary tubes are presented, together with the experimental results for straight capillary tubes obtained by previous researchers. The results show that the refrigerant flowing through the straight capillary tube provides a slightly lower pressure drop than that in the helical capillary tube, which resulted in a total tube length that was longer by about 20%. In addition, for the same tube length, the mass flow rate in the helical capillary tube with a coil diameter of 40 mm is 9% less than that in the straight tube. Finally, the results obtained from the present model show reasonable agreement with the experimental data of helical capillary tubes and can also be applied to predict the flow characteristics of straight capillary tubes by changing to straight tube friction factors, for which Churchill's equation was used in the present study.

12/00780 An integrated thermal and mechanical investigation of molten-salt thermocline energy storage

Flueckiger, S. *et al. Applied Energy*, 2011, 88, (6), 2098–2105.

Thermal ratcheting is a critical phenomenon associated with the cyclic operation of dual-medium thermocline tanks in solar energy applications. Although thermal ratcheting poses a serious impediment to thermocline operation, this failure mode in dual-medium thermocline tanks is not yet well understood. To study the potential for the occurrence of ratcheting, a comprehensive model of a thermocline tank that includes both the heterogeneous filler region as well as the composite tank wall is formulated. The filler region consists of a rock bed with interstitial molten salt, while the tank wall is composed of a steel shell with two layers of insulation (firebrick and ceramic). The model accounts separately for the rock and molten-salt regions in view of their different thermal properties. Various heat loss conditions are applied at the external tank surface to evaluate the effect of energy losses to the surroundings. Hoop stresses, which are governed by the magnitude of temperature fluctuations, are determined through both a detailed finite-element analysis and simple strain relations. The two methods are found to yield almost identical results. Temperature fluctuations are damped by heat losses to the surroundings, leading to a reduction in hoop stresses with increased heat losses. Failure is prevented when the peak hoop stress is less than the material yield strength of the steel shell. To avoid ratcheting without incurring excessive energy loss, insulation between the steel shell and the filler region should be maximized.

12/00781 An investigation of the solar powered absorption refrigeration system with advanced energy storage technology

Xu, S. M. *et al. Solar Energy*, 2011, 85, (9), 1794–1804.

This paper presented a new solar powered absorption refrigeration (SPAR) system with advanced energy storage technology. The advanced energy storage technology referred to the Variable Mass Energy Transformation and Storage (VMETS) technology. The VMETS technology helped to balance the inconsistency between the solar radiation and the air conditioning (AC) load. The aqueous lithium bromide (H_2O–LiBr) was used as the working fluid in the system. The energy collected from the solar radiation was first transformed into the chemical potential of the working fluid and stored in the system. Then the chemical potential was transformed into thermal energy by absorption refrigeration when AC was demanded. In the paper, the working principle and the flow of the SPAR system were explained and the dynamic models for numerical simulation were developed. The numerical simulation results can be used to investigate the behaviour of the system, including the temperature and concentration of the working fluid, the mass and energy in the storage tanks, the heat loads of heat exchanger devices and so on. An example was given in the paper. In the example, the system was used in a subtropical city like Shanghai in China and its operating conditions were set as a typical summer day: the outdoor temperature varied between 29.5 °C and 38 °C, the maximum AC load was 15.1 kW and the total AC capacity was 166.1 kW h (598.0 MJ). The simulation results indicated that the coefficient of performance (COP) of the system was 0.7525 or 0.7555 when the condenser was cooled by cooling air or by cooling water respectively and the storage density (SD) was about 368.5 MJ/m^3. As a result, the required solar collection area was 66 m^2 (cooling air) or 62 m^2 (cooling water) respectively. The study paves the road for system design and operation control in the future.

12/00782 Analytical and numerical prediction of heat transfer and pressure drop in open-cell metal foams

Bai, M. and Chung, J. N. *International Journal of Thermal Sciences*, 2011, 50, (6), 869–880.

Enhanced cooling methods are needed for advanced power systems. A promising method is using an open-cell metal foam to improve the heat transfer rates. However, the pressure drop induced by the metal foams is relatively higher and thus becomes a critical issue in engineering applications. The focus of this research is the modelling and simulation of heat transfer enhancement and corresponding pressure drop. A simplified analytical model based on diamond-shaped unit cells has been developed to predict the heat transfer capability of a foamed channel. The heat transfer rates predicted by the analytical model have been compared with available experimental data from other researchers and favourable agreements have been obtained. To evaluate the pressure drop in metal foams, a unit-cell CFD model was built using the software package Fluent. The model is based on a structure of sphere-centred open-cell tetrakaidecahedron, which is very similar to the actual microstructure of an aluminium metal foam. Flow patterns and grid independence are investigated and simulation results are shown to agree well with experimental data.

12/00783 Analytical *g*-function for inclined boreholes in ground-source heat pump systems

Lamarche, L. *Geothermics*, 2011, 40, (4), 241–249.

In the design of ground-source heat pump systems, the calculation of the total length of the bore field is very important because it is responsible for the major part of the initial cost. Some technologies, like direct expansion systems and pile systems, often use inclined boreholes. Most design methods do not consider this effect and may overestimate the total length needed for a typical application. This paper gives a method for the calculation of time response factors in a form called *g*-function for inclined boreholes. The analytical model can be used in a parameterized optimization algorithm to design an optimum bore field. The method is a generalization of a method previously proposed for vertical boreholes. Comparison of the new *g*-function with tabulated values found in the literature is given, and an application for a typical design is presented as an example.

12/00784 Bio-thermal convection induced by two different species of microorganisms

Kuznetsov, A. V. *International Communications in Heat and Mass Transfer*, 2011, 38, (5), 548–553.

This paper develops a theory of biothermal convection in a suspension that contains two species of microorganisms exhibiting different taxes, gyrotactic and oxytactic microorganisms. The developed theory is applied to investigating the onset of bio-thermal convection in such a suspension occupying a horizontal layer of finite depth. A linear stability analysis is utilized to derive the equations for the amplitudes of disturbances. The obtained eigenvalue problem is solved by the Galerkin method. The case of non-oscillatory instability in a layer with a rigid lower boundary and a stress-free upper boundary is investigated. The resulting eigenvalue equation relates three Rayleigh numbers, the traditional Rayleigh number (Ra) and two bioconvection Rayleigh numbers, one for gyrotactic (Rb_g) and one for oxytactic (Rb_o) microorganisms. The neutral stability boundary is presented in the form of a diagram showing that boundary in the (Ra, Ra_g) plane for different values of Ra_o.

12/00785 Convective heat transfer on leeward building walls in an urban environment: measurements in an outdoor scale model

Nottrott, A. *et al. International Journal of Heat and Mass Transfer*, 2011, 54, (15–16), 3128–3138.

Convection over the building envelope is a critical determinant of building cooling load, but parameterization of convection in building energy models and urban computational fluid dynamics models is challenging. An experimental investigation intended to clarify the heat transfer mechanism of a convective wall boundary layer (WBL) on a leeward, vertical building wall was conducted at the comprehensive outdoor scale model (COSMO) facility for urban atmospheric research. Comparison of mean and turbulent temperature fluctuation intensity profiles showed that the dominant regime of the WBL flow was turbulent natural convection. Implications for parameterization of convective heat fluxes in urban areas are discussed.

12/00786 Development and validation of static simulation model for CO_2 heat pump

Yamaguchi, S. *et al. International Journal of Heat and Mass Transfer*, 2011, 54, (9–10), 1896–1906.

A simulation model for the CO_2 heat pump water heater was developed and validated in this study. Component models of the gas cooler, evaporator, compressor, and expansion valve were constructed with careful consideration for the heat transfer performances. To validate the simulation model, experiments were carried out using an actual CO_2 heat pump water heater (water heating capacity: 22.3 kW; hot-water temperature: 90 °C). In simulations and experiments, the effects of the inlet water temperature and outside air temperature on the system characteristics were discussed. As a result, the average difference in COP between the simulation results and experimental results is 1.5%.

12/00787 Dynamic model for multi-compartment indirect cooling household refrigerator using Z-transfer function based cabinet model

Lin, E. *et al. International Journal of Thermal Sciences*, 2011, 50, (7), 1308–1325.

This paper presents a dynamic model for multi-compartment indirect cooling household refrigerator, in which a Z-transfer function based cabinet sub-model, a semi-dynamic compressor sub-model, an approximate analytic capillary sub-model integrated with effective enthalpy method, a multi-zone heat exchanger sub-model, and an implicit curve-fitting method for refrigerant thermodynamic properties are integrated. The model is carried out with the predictor–corrector method as well as the adaptive time step algorithm and the time step interpolation method to match the adaptive time step for dynamic model and the fixed time step for cabinet model. A case study shows that the calculation speed of the Z-transfer function based cabinet sub-model is about 40,000 times faster than that based on direct differential equation solving with a difference of less than 0.06 °C in predicting air temperature with these two methods. Simulation of 24-h running process of a refrigerator by the dynamic model on a personal computer costs 178.3 s; and the differences between the predictions and the experimental data are within 2 °C for compartment air temperature, within 2 °C for evaporating/condensing temperature, and within 10% for compressor input power.

12/00788 Effect of the load condition on frictional heat generation and temperature increase within a tri-cone bit during high-temperature formation drilling

Suto, Y. and Takahashi, H. *Geothermics*, 2011, 40, (4), 267–274.

To investigate the effect of the load condition on frictional heat and temperature within a tri-cone bit, a series of experiments were performed to simulate the mechanical conditions during drilling. The bearing characteristic number, which indicates load conditions such as rotation speed, weight on the bit, and flow resistance, was used to interpret the results. The Stribeck curve of the bearing shows the bearing was in a state of mixed (boundary + elasto-hydrodynamic) lubrication, not in a smooth hydrodynamic lubrication. When drilling high-temperature formations, the bottomhole temperature is higher than that in the experiment, and mixed lubrication progresses to boundary lubrication. The temperature within the bit increases readily, damaging the O-ring seal in the journal bearing.

12/00789 Effect of wall orientation on the optimum insulation thickness by using a dynamic method

Ozel, M. *Applied Energy*, 2011, 88, (7), 2429–2435.

A comprehensive economic analysis has been performed to inter-relate the optimum thickness of insulation materials for various wall orientations. The yearly cooling and heating transmission loads of building walls were determined by use of implicit finite-difference method with regarding steady periodic conditions under the climatic conditions of Elazığ, Turkey. The economic model including the cost of insulation material and the present value of energy consumption cost over lifetime of 10 years of the building was used to find out the optimum insulation thickness, energy savings and payback periods for all wall orientations. Considered insulation materials in the analysis were extruded polystyrene and polyurethane. As a result, the optimum insulation thickness of extruded polystyrene was found to be 5.5 cm for south oriented wall and 6 cm for north, east and west oriented walls. Additionally, the lowest value of the optimum insulation thickness and energy savings were obtained for the south oriented wall while payback period was almost same for all orientations.

12/00790 Effects of nano-SiO_2 on morphology, thermal energy storage, thermal stability, and combustion properties of electrospun lauric acid/PET ultrafine composite fibers as form-stable phase change materials

Cai, Y. *et al. Applied Energy*, 2011, 88, (6), 2106–2112.

The ultrafine composite fibres consisting of lauric acid (LA), polyethylene terephthalate (PET), and silica nanoparticles (nano-SiO_2) were prepared through the materials processing technique of electrospinning as an innovative type of form-stable phase change materials (PCMs). The effects of nano-SiO_2 on morphology, thermal energy storage, thermal stability, and combustion properties of electrospun LA/PET/SiO_2 composite fibres were studied. SEM images revealed that the LA/PET/SiO_2 composite fibres with nano-SiO_2 possessed desired morphologies with reduced average fibre diameters as compared to the LA/PET fibres without nano-SiO_2. DSC measurements indicated that the amount of nano-SiO_2 in the fibres had an influence on the crystallization of LA, and played an important role on the heat enthalpies of the composite fibres; while it had no appreciable effect on the phase change temperatures. TGA results suggested that

the incorporation of nano-SiO_2 increased the onset thermal degradation temperature, maximum weight loss temperature, and charred residue at 700 °C of the composite fibres, indicating the improved thermal stability of the fibres. MCC tests showed that the heat resistance effect and/or barrier property generated by nano-SiO_2 resulted in an increase of initial combustion temperature and a decrease of the heat release rate for the electrospun ultrafine composite fibres.

12/00791 Effects of pressure work and radiation on natural convection flow around a sphere with heat generation

Miraj, M. *et al. International Communications in Heat and Mass Transfer*, 2011, 38, (7), 911–916.

The effects of pressure work and radiation on natural convection flow around a sphere in presence of heat generation have been investigated in this paper. The governing equations are transformed into dimensionless non-similar equations by using set of suitable transformations and solved numerically by the finite difference method along with Newton's linearization approximation. Attention has been focused on the evaluation of shear stress in terms of local skin friction and rate of heat transfer in terms of local Nusselt number, velocity as well as temperature profiles. Numerical results have been shown graphically and also in tabular form for some selected values of parameter set consisting of heat generation parameter *Q*, radiation parameter *Rd*, pressure work parameter *Ge* and the Prandtl number *Pr*.

12/00792 Effects of water contamination on sub-cooled flow boiling heat transfer

Helali, A. B. *Energy Conversion and Management*, 2011, 52, (5), 2288–2295.

An experimental investigation has been carried out to study the effect of adding four different contaminants to distilled water on heat transfer under sub-cooled flow boiling conditions. Flow boiling experimental test rig has been designed and constructed to study the effect of changing the contaminant concentration and flow velocity. Lube oil, Nile river water, tap water and sea water were added at different concentrations to distilled water under sub-cooled flow boiling testing at constant bulk temperature. The effect of flow velocity was also studied for three different concentrations of 1%, 3% and 5% as compared to pure distilled water case. The heat flux applied was in the range of 100–400 kW/m^2. Flow velocities were changed from 1, 2 to 2.5 m/s at constant bulk temperature of 70 °C. It was found that adding any of the contaminants at all considered concentrations to distilled water impairs the heat transfer process substantially.

12/00793 Enhancement of latent heat energy storage using embedded heat pipes

Robak, C. W. *et al. International Journal of Heat and Mass Transfer*, 2011, 54, (15–16), 3476–3484.

Latent heat thermal energy storage (LHTES) utilizing heat pipes or fins is investigated experimentally. Photographic observations, melting and solidification rates, and PCM energy storage quantities are reported. Heat pipe effectiveness is defined and used to quantify the relative performance of heat pipe-assisted and fin-assisted configurations to situations involving neither heat pipes nor fins. For the experimental conditions of this study, inclusion of heat pipes increases PCM melting rates by approximately 60%, while the fins are not as effective. During solidification, the heat pipe-assisted configuration transfers approximately twice the energy between a heat transfer fluid and the PCM, relative to both the fin-assisted LHTES and the non-heat pipe, non-fin configurations.

12/00794 Evaluating the use heat pipe for dedicated ventilation of office buildings in Hong Kong

Zhang, L. and Lee, W. L. *Energy Conversion and Management*, 2011, 52, (4), 1983–1989.

Recent research studies advocates decoupling dehumidification from cooling to improve indoor air quality and reduce energy consumption. The feasible use of heat pipe at the air handler dedicated for outdoor air treatment (HPDV system) in accomplishing this objective is investigated in this study. To evaluate the performance and the energy saving potential of the proposed HPDV system, the design parameters of 75 grade A office buildings in Hong Kong were collected. Ten representative buildings were subsequently identified for further study to achieve a confidence level of 95%. The annual cooling load profiles of the 10 representative buildings were simulated by the use of HTB2. Based on the realistic cooling load profiles and the heat pipes of effectiveness 0.35–0.6, the proposed HPDV system in achieving the intended objectives were evaluated. It was found that the savings for the 10 representative buildings were comparable. The reduction in cooling and reheating energy was between 23 and 44 kWh/m^2, which corresponds to 1.2% and 7.9% saving in annual energy use for air-conditioning. The results indicate that HP of different effectiveness can be applied to save energy for over 70% of the air-conditioned hours; of which only 0.03–6.3% of the time the decoupling objective cannot be achieved (abbreviated as NHRS). Based on the results of the study, a simplified model relating NHRS with heat pipe effectiveness has been established. The model can help designers more quickly determine how NHRS can be weighted against other factors such as the additional plant room space and the financial implications. The results confirm the feasible use of the HPDV system in achieving the intended objectives for subtropical climate like Hong Kong where air-conditioning demand is highly variable, and is required year-round.

12/00795 Experimental and numerical investigation of a phase change material: thermal-energy storage and release

Joulin, A. *et al. Applied Energy*, 2011, 88, (7), 2454–2462.

The application of phase change materials (PCMs) for solar thermal-energy storage capacities has received considerable attention in recent years due to their large storage capacity and isothermal nature of the storage process. This study deals with the comparison of numerical and experimental results for a PCM conditioned in a parallelepipedic polyefin envelope to be used in passive solar walls. The experimental results were obtained by use of a genuine set-up involving heat flux sensors and thermocouples mounted on two vertical aluminium exchanger plates squeezing the samples. Numerical predictions were obtained with a custom one-dimensional Fortran code and a two-dimensional use of Fluent. Both methods showed a very good agreement with experimental observations for the melting process ($\geq$5%). However during solidification, both numerical codes failed to predict the phase change process accurately, the maximal relative error was as high as 57% (with an average of 8%).

12/00796 Galactitol hexa stearate and galactitol hexa palmitate as novel solid–liquid phase change materials for thermal energy storage

Sari, A. *et al. Solar Energy*, 2011, 85, (9), 2061–2071.

Galactitol has a melting point of 187.41 °C and a fusion enthalpy of 401.76 J g^{-1}. Its melting temperature is not suitable for many thermal energy storage applications although it has good latent heat storage capacity compared to the several traditional phase change materials (PCMs). The galactitol also has high supercooling degree as about 72 °C. These unfavourable properties limit the usage potential of galactitol in thermal energy storage applications. However, the phase change temperature and supercooling degree of galactitol can be reduced to a reasonable value and therefore its feasibility for energy storage systems can be increased. For this aim, in this study, galactitol hexa stearate (GHS) and galactitol hexa palmitate (GHP) were prepared as novel solid–liquid PCM by means of esterification reaction of the galactitol with palmitic acid and stearic acid. The GHP and GHS esters were characterized chemically using FT-IR and ^{1}H NMR techniques. By using DSC analysis method, the melting temperature and latent heat value of the PCMs were determined as 31.78 °C and 201.66 J g^{-1} for GHP ester and 47.79 °C and 251.05 J g^{-1} for GHS ester. Thermal cycling test showed that the prepared PCMs had good thermal reliability after thermal 1000 melting–freezing cycles. Thermogravimetric analysis (TGA) results revealed that the PCMs have good thermal stability over their working temperatures. In addition, thermal conductivity of the prepared PCMs was increased as about 26.3% for GHP and 53.3% for GHS by addition of 5 wt% expanded graphite. Based on all results it can be concluded that the prepared GHP and GHS esters can be considered as promising solid–liquid PCMs for many energy storage applications such as solar energy storage, indoor temperature controlling in buildings, production of smart textile and insulation clothing due to their good energy storage properties.

12/00797 Geometry development of the internal duct system of a heat pump tumble dryer based on fluid mechanic parameters from a CFD software

Rezk, K. and Forsberg, J. *Applied Energy*, 2011, 88, (5), 1596–1605.

One aspect of reducing the energy consumption of a household tumble dryer is to reduce the pressure drop of the circulating air in the internal duct system. It is, however, costly and time consuming to design several prototypes for airflow measurements. In this paper, several fluid mechanic parameters in a partial model of the internal duct system of a tumble dryer have been studied in the CFD software Comsol MultiPhysics. The purpose was to establish a numerically based design process, where the design is conducted based on visual analysis of air velocity and vorticity, and two design criteria. The geometry design was conducted by a CAD-engineer, which was the counterpart of this project. In order to enable a successful design process, it was essential to establish a strong relation between fluid parameters and design criteria in order to share knowledge effectively with the CAD-engineer. Two geometry modifications, based on a standard model, were conducted on the duct. Based on the design criteria, the pressure drop and the non-uniformity coefficient of the outlet airflow, the second modification (Modification 2) represents an improvement as the pressure drop is reduced by 23% and the uniformity at the outflow section is increased by 3%.

12/00798 Harnessing the energy accompanying freezing

Akyurt, M. and Türkmen, N. *Energy Conversion and Management*, 2011, 52, (5), 2241–2246.

The progression of freezing of water inside a pipe is reviewed, with special emphasis on bursting. The process of pressure rise in confined bodies of water is discussed. The development of a method utilizing liquid carbon dioxide and liquid nitrogen, for the development of pressures inside closed containers is summarized. Then a novel method, utilizing mechanical refrigeration, is explained for the generation of high pressures. An experimental setup for the latter technique is described and results of experiments are summarized. A number of ways of utilizing the ice-pressurization technique are presented. Certain characteristics and advantages of ice-pressurization are enumerated as regards to burst and leak testing. It is noted that a number of other techniques such as shrink fitting, embossing and compaction of powders also seem to be particularly suitable. It is concluded that, with the advent of the portable and novel chilling apparatus, new vistas are approachable for undertaking maintenance operations in hospitals, power plants, nuclear facilities, and other systems that require uninterrupted operation.

12/00799 Heat pipe with PCM for electronic cooling

Weng, Y.-C. *et al. Applied Energy*, 2011, 88, (5), 1825–1833.

This article experimentally investigates the thermal performances of a heat pipe with phase change material for electronic cooling. The adiabatic section of heat pipe is covered by a storage container with phase change material (PCM), which can store and release thermal energy depending upon the heating powers of evaporator and fan speeds of condenser. Experimental investigations are conducted to obtain the system temperature distributions from the charge, discharge and simultaneous charge/discharge performance tests. The parameters in this study include three kinds of PCMs, different filling PCM volumes, fan speeds, and heating powers in the PCM cooling module. The cooling module with tricosane as PCM can save 46% of the fan power consumption compared with the traditional heat pipe.

12/00800 Method for optimal design of pipes for low-energy district heating, with focus on heat losses

Dalla Rosa, A. *et al. Energy*, 2011, 36, (5), 2407–2418.

The synergy between highly energy-efficient buildings and low-energy district heating (DH) systems is a promising concept for the optimal integration of energy-saving policies and energy supply systems based on renewable energy (RE). Network transmission and distribution heat loss is one of the key factors in the optimal design of low-energy DH systems. Various pipe configurations are considered in this paper: flexible pre-insulated twin pipes with symmetrical or asymmetrical insulation, double pipes, and triple pipes. These technologies represent potential energy-efficient and cost-effective solutions for DH networks in low-heat density areas. The paper starts with a review of theories and methods for steady-state heat loss calculation. Next, it shows how detailed calculations with 2D-modelling of pipes can be carried out by means of computer software based on the finite element method (FEM). The model was validated by comparison with experimental measurements, analytical formulas, and data from the literature. The authors took into account the influence of the temperature-dependent conductivity coefficient of polyurethane insulation foam, which enabled us to achieve a high degree of accuracy. They also showed the influence of the soil temperature throughout the year. Finally, the article describes proposals for the optimal design of pipes for low-energy applications and presents methods for decreasing heat losses.

12/00801 Modeling of a flat plate membrane-distillation system for liquid desiccant regeneration in air-conditioning applications

Rattner, A. S. *et al. International Journal of Heat and Mass Transfer*, 2011, 54, (15–16), 3650–3660.

A thermally driven flat plate air gap membrane distillation liquid desiccant regenerator for lithium chloride in dehumidification applications is modelled. Operating conditions and device geometry are optimized, and it is found that membrane materials have little influence on regenerator performance. It is shown that radiation heat transfer across the air gap cannot be neglected. The regenerator removes 11.4 g min^{-1} cm^{-3} of moisture with a COP of 0.372 for an inlet solution concentration of 0.38, solution flow rate of 50 ml min^{-1}, and heated solution temperature of 135 °C. This design has negligible desiccant carry-over losses and operates without a blower.

12/00802 Multi-year application of the three-dimensional numerical generation of response factors (NGRF) method in the prediction of conductive temperatures in soil and passive cooling earth-contact components

Zoras, Z. *et al. Solar Energy*, 2011, 85, (9), 2275–2282.

A recently developed method named the three-dimensional numerical generation of response factors NGRF was claimed to be fast, accurate and flexible as a result of incorporating elements of the response factor method into a finite volume technique based numerical model. The presented paper reports on the application of the NGRF method for the numerical prediction of temperatures within and around structural passive cooling components over multi-year temperature profiles. Once the numerical temperature response factors time series of an earth-contact component's grid node had been generated then its future thermal performance due to any surrounding temperature variation can be predicted fast and accurately. The NGRF method was, successfully, applied through an intermodel testing procedure to simulate soil and structural earth-contact passive cooling component temperatures for multiple years.

12/00803 Natural convection of water–CuO nanofluid in a cavity with two pairs of heat source–sink

Aminossadati, S. M. and Ghasemi, B. *International Communications in Heat and Mass Transfer*, 2011, 38, (5), 672–678.

Natural convection in a two-dimensional square cavity filled with a water–CuO nanofluid is numerically studied. Two pairs of heat source–sink are considered to cover the entire length of the bottom wall of the cavity while the other walls are thermally insulated. The nanofluid is assumed to be homogenous and Newtonian. The governing differential equations are discretized by the control volume approach and the coupling between velocity and pressure is solved using the SIMPLE algorithm. A comparison study is presented between two cases with different arrangements of the two pairs on the bottom wall. The effects of Rayleigh number and solid volume fraction of the nanofluid on the heat transfer rate have also been examined. The results show that regardless of the position of the pairs of source–sink, the heat transfer rate increases with an increase of the Rayleigh number and the solid volume fraction.

12/00804 One thousand thermal cycles of magnesium chloride hexahydrate as a promising PCM for indoor solar cooking

El-Sebaii, A. A. *et al. Energy Conversion and Management*, 2011, 52, (4), 1771–1777.

Cooking is the major necessity for people all over the world. It accounts for a major share of energy consumption in developing countries. There is a critical need for the development of alternative, appropriate, affordable methods of cooking for use in developing countries. There is a history for solar cooking since 1650 where they are broadly divided into direct or focusing type, box-type and indirect or advanced solar cookers. The advanced solar cookers have the advantage of being usable indoors and thus solve one of the problems, which impede the social acceptance of solar cookers. The advanced type solar cookers are employing additional solar units that increase the cost. Therefore, the solar cooker must contain a heat storage medium to store thermal energy for use during off-sunshine hours. The main aim of this paper is to investigate the influence of the melting/solidification fast thermal cycling of commercial grade magnesium chloride hexahydrate ($MgCl_2{\cdot}6H_2O$) on its thermo-physical properties; such as melting point and latent heat of fusion, to be used as a storage medium inside solar cookers. One thousand cycles have been performed in a sealed container under the extra water principle. The thermo-physical properties are measured using the differential scanning calorimetric technique. It is indicated that $MgCl_2{\cdot}6H_2O$ with the extra water principle and hermetically sealing of the container is a promising phase change material (PCM) for cooking indoors and during law intensity solar radiation periods. It is also found from the melting/solidification behaviour of $MgCl_2{\cdot}6H_2O$ that it is solidify almost without supercooling; except in few cases where it showed maximum of 0.1–3.5 °C of supercooling.

12/00805 Parametric study on the effect of end walls on heat transfer and fluid flow across a micro pin-fin

Koz, M. *et al. International Journal of Thermal Sciences*, 2011, 50, (6), 1073–1084.

Micro heat sinks have a broad applicability in many fields such as aerospace applications, micro turbine cooling, micro reactors, electronics cooling, and micro biological applications. Among different types of micro heat sinks, those with micro pin-fins are becoming popular due to their enhanced heat removal performance. However, relevant experimental data in current literature is still scarce to adequately explain their differences from their macro size counter parts. In previous studies in literature, it was shown that thermal and hydrodynamic characteristics of micro pin-fin heat sinks are strongly affected by height over diameter (H/D) ratio of pin-fins. To address the lack of information about this subject, the objective of this work is to show how velocity boundary layer around pin-fins and consequently, the thermal and hydrodynamic characteristics are affected when H/D ratio and local Reynolds number (Re) vary. To investigate end wall effects, a small portion of a typical micro pin-fin heat sink is modelled. This portion is represented by a simplified model, which consists of a single pin-fin positioned in a rectangular micro channel. This approach simplified the micro heat sink, which is simulated for only half of it by

using a symmetry plane. Moreover, the transverse channel walls are kept as close as the minimum distance (1.5D) between pin-fins available in the literature. In this paper, the pin-fin height over diameter ratio, H/D, varies from 0.5 to 5, while Re and heat flux provided from the fluid interacting surfaces of the micro pin-fin are in the range of $20 \leq Re \leq 150$ and $100 \leq q_{in}\,(W/cm^2) \leq 500$, respectively. In this research, micro pin-fin heat sinks are three dimensionally modelled on a one-to-one scale with the use of commercially available software COMSOL Multiphysics 3.5a. Full and temperature dependent Navier–Stokes equations subjected to compressibility and energy equations are solved under steady state conditions. In order to validate the use of numerical models, simulation results are compared against theoretical predictions. The numerical results and theoretical predictions show a good agreement. After this validation, parametric analysis is performed using the three dimensional model developed with COMSOL Multiphysics 3.5a. The end wall effects are quantified, and this amount decreases with Re and H/D. It is revealed that end walls play an important role on the total fluidic force acting on the micro pin-fin and on the heat transfer coefficients. Moreover, the trends in the amount of end walls effects, the ratio of viscous over total forces on the pin-fin, friction factors, and Nusselt numbers change at various critical Re numbers. It is also demonstrated that increasing H/D ratio leads to a less stable flow, higher fluidic forces on the micro pin-fin with an increased partial role of viscous forces relative to pressure forces, smaller friction factors, and higher heat transfer coefficients. There are maxima and minima in Nusselt number profiles for different H/D ratios. It is found that increasing Re has a positive role in Nusselt numbers, as well as a parallel effect with H/D on fluidic forces on micro pin-fin, friction factors, and heat transfer coefficients. Different than the effect of H/D, Re decreases the partial role of viscous forces relative to pressure forces.

12/00806 Performance of a gas engine driven heat pump for hot water supply systems

Elgendy, E. *et al. Energy*, 2011, 36, (5), 2883–2889.

The present work aimed at evaluating the experimental performance of a gas engine heat pump for hot water supply. In order to achieve this objective, a test facility was developed and experiments were performed over a wide range of ambient air temperature (10.9–25.3 °C), condenser water inlet temperature (33–49 °C) and at two engine speeds (1300 and 1750 rpm). Performance characteristics of the gas engine heat pump were characterized by water outlet temperatures, total heating capacity and primary energy ratio. The reported results revealed that hot water outlet temperature between 35 and 70 °C can be obtained over the considered range of the operating parameters. Also, total heating capacity and gas engine heat recovery decrease by 9.3 and 27.7%, respectively, while gas engine energy consumption increases by 17.5% when the condenser water inlet temperature changes from 33 to 49 °C. Total heating capacity, gas engine heat recovery and gas engine energy consumption at ambient air temperature of 25.3 °C are higher than those at ambient air temperature of 10.9 °C by about 10.9, 6.3 and 1.5% respectively. Moreover, system primary energy ratio decreases by 15.3% when the engine speed changes from 1300 to 1750 rpm.

12/00807 Physical mechanisms involved in grooved flat heat pipes: experimental and numerical analyses

Lips, S. *et al. International Journal of Thermal Sciences*, 2011, 50, (7), 1243–1252.

An experimental database, obtained with flat plate heat pipes (FPHP) with longitudinal grooves is presented. The capillary pressure measured by confocal microscopy and the temperature field in the wall are presented in various experimental conditions (vapour space thickness, filing ratio, heat transfer rate, tilt angle, fluid). Coupled hydrodynamic and thermal models are developed. Experimental results are compared to results of numerical models. Physical mechanisms involved in grooved heat pipes are discussed, including the boiling limit and the effect of the interfacial shear stress. Finally, recommendations for future experimental and theoretical research to increase the knowledge on FPHP are discussed.

12/00808 Pneumatic and thermal design procedure and analysis of earth-to-air heat exchangers of registry type

Badescu, V. and Isvoranu, D. *Applied Energy*, 2011, 88, (4), 1266–1280.

An analytical pneumatic and thermal design procedure is proposed for earth-to-air heat exchangers (EAHEs) of registry type. The procedure allows to choosing between different EAHE geometrical configurations and between the two usual air circulation paths inside the EAHE (i.e. the Z- and Π-paths, respectively). The implementation of the design procedure is made for the EAHE of a large passive house (PH) built near Bucharest, Romania (AMVIC PH). A time-dependent simulation of EAHE's operation is performed. It allows to computing the soil temperature profile at the surface and at various depths and the air temperature distribution inside the EAHE. This simulation is validated by comparison with experimental results. The EAHE heating and cooling potential during the year is investigated. The energy delivered by the EAHE depends significantly on its geometrical configuration. A computer fluid dynamics (CFD) analysis is also performed. This analysis is validated by comparison with experimental results. There is good agreement between the results predicted by the design procedure and the CFD analysis concerning the air pressure drops in the EAHE. From a thermal point of view the Z-path should be preferred to the Π-path. The CFD analysis results confirm the conclusions stressed out from the simple analytic design procedure and the time-dependent simulation.

12/00809 Thermal Barrier as a technique of indirect heating and cooling for residential buildings

Krzaczek, M. and Kowalczuk, Z. *Energy and Buildings*, 2011, 43, (4), 823–837.

The paper presents a concept of an indirect heating and cooling technique of residential buildings driven by solar thermal radiation called Thermal Barrier (TB), which is composed of polypropylene U-pipes located inside of external walls. Fluid flows inside a U-pipes system with a variable mass flow rate and variable supply temperature. This creates a semi-surface parallel to wall surfaces and a spatially averaged temperature almost constant and close to the reference temperature of 17 °C all year round. The TB technique is used to stabilize and reduce heat flux normal to the wall surface and to maintain its direction from internal air out to ambient air during the entire year. The main intention of this paper was to investigate the thermal performance and stability of the TB. A three-dimensional finite elements model of a prefabricated external wall component containing a TB U-pipe system with flowing fluid was developed using the finite elements code ABAQUS. The finite elements analysis was supported by a novel SVC control system implemented in FORTRAN to simulate real-working conditions. The advantages of the TB heating/cooling technique are outlined.

12/00810 Thermal transport analysis in parallel-plate channel filled with open-celled metallic foams

Xu, H. J. *et al. International Communications in Heat and Mass Transfer*, 2011, 38, (7), 868–873.

Forced convective heat transfer in highly porous, open-celled metallic foams sandwiched between two infinite parallel plates is analytically modelled using the Brinkman–Darcy and two-equation models. With uniform heat flux, closed-form solutions for fully developed flow and heat transfer are obtained. Nusselt number with explicit expression is derived and the analytical results are verified by existing experimental data. To examine the effect of axial heat conduction neglected in the analytical modelling, numerical simulations, which are verified by the analytical solution, are performed. A modified fin analysis method with improved predicting accuracy compared with the conventional fin analysis method by introducing equivalent foam temperature is also put forward. The predictions obtained with the analytical model, the numerical simulation and the modified fin analysis method are compared with each other, and their pros and cons are discussed. Finally, a systematic parametric study is conducted on heat transfer in parallel-plate channels filled with metallic foams, with useful suggestions for practical designs obtained.

12/00811 Thermodynamic analysis of transcritical CO_2 booster refrigeration systems in supermarket

Ge, Y. T. and Tassou, S. A. *Energy Conversion and Management*, 2011, 52, (4), 1868–1875.

Due to less environmental impact, the CO_2 booster refrigeration system has been widely applied in the modern supermarket as a substitute for the conventional R404A multiplex system. However, the performance efficiency of the CO_2 system still requires further improvement in order to save energy; thus, one of the most efficient techniques would be to investigate and employ the optimal controls for refrigerant high side pressures at various operating states. In this paper, the possible parameters affecting system efficiency of the CO_2 system in the transcritical cycle at a higher ambient air temperature are identified through thermodynamic analysis, but cannot be quantified mathematically because of the high non-linearity involved. Instead, sensitive analyses of the system by means of the thermodynamic model is used to examine the effects of parameters including high side refrigerant pressure, ambient air temperature, refrigerant intermediate pressure, and medium and low evaporating temperatures, superheating, effectiveness of suction line heat exchanger, and compressor efficiency on system performance. Consequently, the optimal high side pressure in the transcritical cycle is established and derived as a function of three important parameters consisting of ambient air temperature, the effectiveness of suction line heat exchanger and compressor efficiency. In addition, optimal operating parameters such as the intermediate pressure are also proposed to improve the system performance.

12/00812 Use of RF electric fields for simultaneous mineral and bio-fouling control in a heat exchanger
Kim, W. *et al. International Communications in Heat and Mass Transfer*, 2011, 38, (8), 1003–1007.
This study investigates the effectiveness of a physical water treatment (PWT) technology using oscillating RF (radio frequency) electric fields in water to mitigate both mineral and bio-fouling in a cooling water application. Heat transfer tests were conducted using a laboratory-scale cooling tower to determine fouling resistance over time, and bio-fouling tests were performed using a heterotrophic plate count method to measure colony-forming units (CFU) values per millilitre of cooling water. The results indicated that the present PWT technology could provide an effective mineral fouling prevention by maintaining 90% of the peak heat transfer performance of a heat exchanger, while effectively controlling water-borne microbial organisms.

11 ENGINES

Power generation and propulsion, electrical vehicles

12/00813 Experimental investigation on the effect of intake air temperature and air–fuel ratio on cycle-to-cycle variations of HCCI combustion and performance parameters
Maurya, R. K. and Agarwal, A. K. *Applied Energy*, 2011, 88, (4), 1153–1163.
Combustion in HCCI engines is a controlled auto ignition of well-mixed fuel, air and residual gas. Since onset of HCCI combustion depends on the auto ignition of fuel/air mixture, there is no direct control on the start of combustion process. Therefore, HCCI combustion becomes unstable rather easily, especially at lower and higher engine loads. In this study, cycle-to-cycle variations of a HCCI combustion engine fuelled with ethanol were investigated on a modified two-cylinder engine. Port injection technique is used for preparing homogeneous charge for HCCI combustion. The experiments were conducted at varying intake air temperatures and air–fuel ratios at constant engine speed of 1500 rpm and P-θ diagram of 100 consecutive combustion cycles for each test conditions at steady state operation were recorded. Consequently, cycle-to-cycle variations of the main combustion parameters and performance parameters were analysed. To evaluate the cycle-to-cycle variations of HCCI combustion parameters, coefficient of variation (COV) of every parameter were calculated for every engine operating condition. The critical optimum parameters that can be used to define HCCI operating ranges are 'maximum rate of pressure rise' and 'COV of indicated mean effective pressure (IMEP)'.

12/00814 Influence of injector technology on injection and combustion development – part 1: hydraulic characterization
Payri, R. *et al. Applied Energy*, 2011, 88, (4), 1068–1074.
An experimental study of two real multi-hole Diesel injectors is performed under current DI Diesel engine operating conditions. The aim of the investigation is to study the influence of injector technology on the flow at the nozzle exit and to analyse its effect on the spray in evaporative conditions and combustion development. The injectors used are two of the most common technologies used nowadays: solenoid and piezoelectric. The nozzles for both injectors are very similar since the objective of the work is the understanding of the influence of the injector technology on spray characteristics for a given nozzle geometry. In the first part of the study, experimental measurements of hydraulic characterization have been analysed for both systems. Analysis of spray behaviour in evaporative conditions and combustion development will be carried out in the second part of the work. Important differences between both injectors have been observed, especially in their transient opening and closing of the needle, leading to a more efficient air–fuel mixing and combustion processes for the piezoelectric actuated injector.

12/00815 On cycle-to-cycle heat release variations in a simulated spark ignition heat engine
Curto-Risso, P. L. *et al. Applied Energy*, 2011, 88, (5), 1557–1567.
The cycle-by-cycle variations in heat release are analysed by means of a quasi-dimensional computer simulation and a turbulent combustion model. The influence of some basic combustion parameters with a clear physical meaning is investigated: the characteristic length of the unburned eddies entrained within the flame front, a characteristic turbulent speed, and the location of the ignition kernel. The evolution of the simulated time series with the fuel–air equivalence ratio, Φ, from lean mixtures to over stoichiometric conditions, is examined and compared with previous experiments. Fluctuations on the characteristic length of unburned eddies are found to be essential to simulate the cycle-to-cycle heat release variations and recover experimental results. A non-linear analysis of the system is performed. It is remarkable that at equivalence ratios around $\Phi \sim 0.65$, embedding and surrogate procedures show that the dimensionality of the system is small.

12/00816 Study of optimal pulverized coal concentration in a four-wall tangentially fired furnace
Tan, H. *et al. Applied Energy*, 2011, 88, (4), 1164–1168.
The effect of fuel lean/rich conditions (1:1, 1:2, 1:3, 1:4, 1:5 and 1:6) on the furnace core temperatures, carbon in fly ash and slag and NO_x emissions was investigated in a 1 MW four-wall tangentially horizontal bias fired furnace for Yibin anthracite and Shenmu bituminous, respectively. Results shown that furnace core temperatures increased at first and then decreased along the height of the furnace when anthracite burned. The furnace core temperature at the height of primary air nozzles was the highest when the bituminous lean/rich varied from 1:1 to 1:3, and its trend was similar to the anthracite when the bituminous lean/rich was changed from 1:4 to 1:6. The ignition of anthracite required a heating stage, while bituminous could timely ignite due to high volatile. However, when the bituminous lean/rich was too low resulting in the relative lack of oxygen, it still needed a heating stage. With increased coal concentration, the furnace core temperatures in the primary air section went up firstly and then down, but the carbon in fly ash and slag showed adverse behaviour. This was due to the high coal concentration corresponding to high volatile concentration leading to the timely ignition and burnout, causing higher furnace core temperature in the primary air section and decreased carbon in fly ash and slag. Corresponding to the highest furnace core temperature in the primary air section and the lowest carbon in fly ash and slag, the optimal pulverized coal concentration of anthracite and bituminous was 0.796–0.810 kg coal/kg air and 0.586–0.607 kg coal/kg air, respectively. In addition, with increased pulverized coal concentration, the NO_x emissions reduced quickly with a slight decrease in the range of the optimal pulverized coal concentration.

12/00817 Theoretical simulation and experimental research on the system of air source energy independence driven by internal-combustion engine
Chen, Y. *et al. Energy and Buildings*, 2011, 43, (6), 1351–1358.
This study presents a new system of air source energy independence driven by internal-combustion engine (EIICE), which uses natural gas or other fuels as an independent input energy, and could provide the heating, cooling and hot water for the buildings efficiently. It also could provide electricity for electric equipment of the system. Experimental and simulation results of the investigation indicated that the heat capacity of the plate heat exchanger (P-HE), heat recovered from the exhaust gas heat exchanger (EG-HE), input power of the compressor, output power of the engine and fuel consumption increased with the increase of the rotary speed, water flow rate of the P-HE and evaporation temperature. Heat recovered from the cylinder jacket heat exchanger (CJ-HE) increased with the increase of the rotary speed and evaporation temperature, but decreased with the increase of the water flow rate of P-HE. The coefficient of performance (COP_t) and primary energy ratio (PER_t) of air source EIICE system also increased with the increase of the water flow rate of P-HE and evaporation temperature, but decreased with the increase of the rotary speed.

12/00818 Three-element model of frictional heating during braking with contact thermal resistance and time-dependent pressure
Yevtushenko, A. A. *et al. International Journal of Thermal Sciences*, 2011, 50, (6), 1116–1124.
The solution to a thermal problem of friction during braking for a three-element tribosystem disc/pad/caliper with time-dependent specific power of friction and heat transfer through a contact surface has been obtained. The influence of duration of increase in pressure (from zero at the initial moment of time to nominal value at the moment of a stop) and the Biot number on the temperature for such materials as cast iron disc/metal–ceramic pad/steel caliper has been studied.

12/00819 Time resolved numerical modeling of oil jet cooling of a medium duty diesel engine piston
Agarwal, A. K. *et al. International Communications in Heat and Mass Transfer*, 2011, 38, (8), 1080–1085.
In medium-to-heavy-duty diesel engines, ever-increasing power densities threat piston structural integrity at high engine loads and speeds. This investigation presents the computational results of the heat transfer between piston and an impinging oil jet, typically used to keep

the pistons cool. Appropriate boundary conditions were applied and using numerical modelling, the heat transfer coefficient (h) at the underside of the piston is predicted. This predicted value of the heat transfer coefficient helps significantly in selecting the right oil (essentially right oil grade), oil jet velocity, nozzle diameter (essentially nozzle design) and distance of the nozzle from the underside of the piston. It also predicts whether the selected grade of oil will contribute to oil fumes/mist generation. Using numerical simulation (finite element method), transient temperature profiles are evaluated for varying heat flux (simulating varying engine loads) to demonstrate the effect of oil jet cooling. The model, after experimental validation, has been used to understand the transient temperature behaviour of the piston and the time taken in achieving steady state. A high-speed CCD camera is used to investigate the oil jet breakup, localized pool boiling and mist generation due to impinging jet on the piston's underside.

Hybrid engine systems

12/00820 Analysis and comparison of performance and emissions of an internal combustion engine fuelled with petroleum diesel and different bio-diesels

McCarthy, P. *et al. Fuel*, 2011, 90, (6), 2147–2157.

The performance and emissions of an internal combustion engine (ICE) engine fuelled with two bio-diesels are experimentally measured and analysed according to ISO 8178 standard and compared with that of the petroleum diesel. Two types of bio-diesel, type A and type B with their blends of B5, B10, B20, B50 and B100 are tested and analysed. This study found that the performance of both bio-diesel fuels reduces with increasing blend ratio, with a torque decrease of 5% for both bio-diesels, and a fuel consumption increase of 7–10%. This can be attributed to the lower energy content of bio-diesel when compared with petroleum diesel. For both the bio-diesels, some emissions were found to be higher than petroleum diesel, while some were lower. Nitrogen oxide (NO_x) emissions decreased by 14% for bio-diesel A, but increased by 17% for bio-diesel B. Carbon monoxides (CO) emissions were significantly reduced for both bio-diesel A and B, with reductions of 58% and 27% respectively. Hydrocarbon (HC) emissions were found to increase with increasing blend ratio for both bio-diesels, with an increase of 10% for bio-diesel A and 80% for bio-diesel B. Lastly, Carbon dioxides (CO_2) emissions were found to increase, with an increase of 6% for bio-diesel A and 18% for bio-diesel B. The study clearly found that each of the bio-diesels has different scale of effect on ICE performance and emissions and hence, it is essential to test bio-diesels before it can be recommended for mass scale production and for commercial use in ICE. However, the study indicates that the two major pollutant gas emissions are generally reduced when using bio-diesel, therefore bio-diesel can be considered to be a more environmentally friendly, secure and renewable approach of obtaining energy in the long run.

12/00821 Comparative characteristics of compression ignited engines operating on biodiesel produced from waste vegetable oil

Yilmaz, N. and Morton, B. *Biomass and Bioenergy*, 2011, 35, (5), 2194–2199.

Performance and emission characteristics of two compression ignited engines of different compression ratios, number of cylinders, cooling system, and power output are studied. Waste vegetable oil-derived biofuel is used. Engines are fuelled with B0, B20 and B100 mixtures. Thermal efficiency, brake specific consumption and engine emissions (CO, unburned HC, O_2 and NO) are reported and comparisons are made for fuel mixtures running on both engines. Trends of emissions and performance curves are compared to the literature of the available data. It is noted that the biofuel certainly affects unburned HC emissions regardless of engine specifications and/or operating conditions. However, the type of fuel or adding biofuel to diesel may not affect parameters such as exhaust gas temperature and emissions (CO, unburned HC, O_2, NO). These parameters may change as functions of engine specifications and operating conditions regardless of biofuel or diesel being used. These findings are supported by separate investigations using different biofuels in literature.

12/00822 Comparison of performance and emissions of a supercharged dual-fuel engine fueled by hydrogen and hydrogen-containing gaseous fuels

Roy, M. M. *et al. International Journal of Hydrogen Energy*, 2011, 36, (12), 7339–7352.

This study investigated the engine performance and emissions of a supercharged engine fuelled by hydrogen (H_2), and three other hydrogen-containing gaseous fuels such as primary fuels, and diesel as pilot fuel in dual-fuel mode. The energy share of primary fuels was about 90% or more, and the rest of the energy was supplied by diesel fuel. The hydrogen-containing fuels tested in this study were 13.7% H_2-content producer gas, 20% H_2-content producer gas and 56.8% H_2-content coke oven gas. Experiments were carried out at a constant pilot injection pressure and pilot quantity for different fuel–air equivalence ratios and at various injection timings. The experimental strategy was to optimize the pilot injection timing to maximize engine power at different fuel–air equivalence ratios without knocking and within the limit of the maximum cylinder pressure. Better thermal efficiency was obtained with the increase in H_2 content in the fuels, and neat H_2 as a primary fuel produced the highest thermal efficiency. The fuel–air equivalence ratio was decreased with the increase in H_2 content in the fuels to avoid knocking. Thus, neat H_2-operation produced less maximum power than other fuels, because of much leaner operations. Two-stage combustion was obtained; this is an indicator of maximum power output conditions and a precursor of knocking combustion. The emissions of CO and HC with neat H_2-operation were 98–99.9% and NO_x about 85–90% less than other fuels.

12/00823 Dynamics of cycle-to-cycle variations in a natural gas direct-injection spark-ignition engine

Sen, A. K. *et al. Applied Energy*, 2011, 88, (7), 2324–2334.

The dynamics of cycle-to-cycle variations (CCV) was investigated in a natural gas direct-injection spark-ignition engine. The method of continuous wavelet transform was used to analyse the time series of the indicated mean effective pressure (IMEP) and other combustion variables. The dominant oscillatory modes in the CCV were identified, and the engine cycles over which these modes may persist were delineated. Results were obtained for four compression ratios: CR = 8, 10, 12 and 14, at two engine speeds of 1200 and 1800 rpm. The results reveal that the CCV exhibit multiscale dynamics with fluctuations occurring at different timescales. At the engine speed of 1200 rpm, the spectral power of CCV for CR = 12 was found to be significantly reduced at the different timescales compared to the CCV at other values of CR. At the higher engine speed of 1800 rpm, this reduction was less pronounced. In addition, cross wavelet transform was used to explore the relationships between the CCV of IMEP and those of flame development duration, main combustion duration and total combustion duration. Strong interdependence was found to exist between the IMEP and main combustion duration as well as total combustion duration, over a wide range of frequencies and engine cycles.

12/00824 Optimization of diesel engine performances for a hybrid wind–diesel system with compressed air energy storage

Ibrahim, H. *et al. Energy*, 2011, 36, (5), 3079–3091.

Electricity supply in remote areas around the world is mostly guaranteed by diesel generators. This relatively inefficient and expensive method is responsible for 1.2 million tons of greenhouse gas (GHG) emission in Canada annually. Some low- and high-penetration wind–diesel hybrid systems (WDS) have been experimented in order to reduce the diesel consumption. The authors explore the re-engineering of current diesel power plants with the introduction of high-penetration wind systems together with compressed air energy storage (CAES). This is a viable alternative to major the overall percentage of renewable energy and reduce the cost of electricity. This paper presents the operative principle of this hybrid system, its economic benefits and advantages and finally proposes a numerical model of each of its components. Moreover, the authors demonstrate the energy efficiency of the system, particularly in terms of the increase of the engine performance and the reduction of its fuel consumption illustrated and supported by a village in northern Quebec.

12/00825 PEM fuel cell modeling using system identification methods for urban transportation applications

Torreglosa, J. P. *et al. International Journal of Hydrogen Energy*, 2011, 36, (13), 7628–7640.

This paper presents a comparative study of proton exchange membrane (PEM) fuel cell (FC) models for integration in hybrid propulsion systems, based on a commercial FC from Nuvera, which is especially manufactured for this application. An existing model is used as a reference in order to build dynamical mathematical models which describe its dynamical behaviour in the time domain. These mathematical models are obtained by applying system identification techniques to the reference model. The proposed FC models have been tested through simulations for the real drive cycle of the existing Metro Centro tramway in Seville.

12/00826 Performance, emission and combustion evaluation of soapnut oil–diesel blends in a compression ignition engine

Misra, R. D. and Murthy, M. S. *Fuel*, 2011, 90, (7), 2514–2518.

Soapnut (*Sapindus mukorossi*) oil, a non-edible straight vegetable oil was blended with petroleum diesel in various proportions to evaluate the performance and emission characteristics of a single cylinder direct

injection constant speed diesel engine. Diesel and soapnut oil (10%, 20%, 30% and 40%) fuel blends were used to conduct short-term engine performance and emission tests at varying loads in terms of 25% load increments from no load to full loads. Tests were carried out for engine operation and engine performance parameters such as fuel consumption, brake thermal efficiency, and exhaust emissions (smoke, CO, UBHC, NO_x, and O_2) were recorded. Among the blends SNO 10 has shown a better performance with respect to BTE and BSEC. All blends have shown higher HC emissions after about 75% load. SNO 10 and SNO 20 showed lower CO emissions at full load. NO_x emission for all blends was lower and SNO 40 blend achieved a 35% reduction in NO_x emission. SNO 10% has an overall better performance with regards to both engine performance and emission characteristics.

Transport battery development

12/00827 A field operational test on valve-regulated lead-acid absorbent-glass-mat batteries in micro-hybrid electric vehicles. Part I. Results based on kernel density estimation

Schaeck, S. *et al. Journal of Power Sources*, 2011, 196, (5), 2924–2932.
In March 2007 the BMW Group has launched the micro-hybrid functions brake energy regeneration (BER) and automatic start and stop function (ASSF). Valve-regulated lead-acid (VRLA) batteries in absorbent glass mat (AGM) technology are applied in vehicles with micro-hybrid power system (MHPS). In both part I and part II of this publication vehicles with MHPS and AGM batteries are subject to a field operational test (FOT). Test vehicles with conventional power system (CPS) and flooded batteries were used as a reference. In the FOT sample batteries were mounted several times and electrically tested in the laboratory intermediately. Vehicle- and battery-related diagnosis data were read out for each test run and were matched with laboratory data in a data base. The FOT data were analysed by the use of two-dimensional, nonparametric kernel estimation for clear data presentation. The data show that capacity loss in the MHPS is comparable to the CPS. However, the influence of mileage performance, which cannot be separated, suggests that battery stress is enhanced in the MHPS although a battery refresh function is applied. Anyway, the FOT demonstrates the unsuitability of flooded batteries for the MHPS because of high early capacity loss due to acid stratification and because of vanishing cranking performance due to increasing internal resistance. Furthermore, the lack of dynamic charge acceptance for high energy regeneration efficiency is illustrated. Under the presented FOT conditions charge acceptance of lead-acid (LA) batteries decreases to less than one third for about half of the sample batteries compared to new battery condition. In part II of this publication FOT data are presented by multiple regression analysis.

12/00828 A field operational test on valve-regulated lead-acid absorbent-glass-mat batteries in micro-hybrid electric vehicles. Part II. Results based on multiple regression analysis and tear-down analysis

Schaeck, S. *et al. Journal of Power Sources*, 2011, 196, (5), 2933–2938.
In the first part of this work a field operational test (FOT) on micro-HEVs (hybrid electric vehicles) and conventional vehicles was introduced. Valve-regulated lead-acid (VRLA) batteries in absorbent glass mat (AGM) technology and flooded batteries were applied. The FOT data were analysed by kernel density estimation. In this publication multiple regression analysis is applied to the same data. Square regression models without interdependencies are used. Hereby, capacity loss serves as dependent parameter and several battery-related and vehicle-related parameters as independent variables. Battery temperature is found to be the most critical parameter. It is proven that flooded batteries operated in the conventional power system (CPS) degrade faster than VRLA–AGM batteries in the micro-hybrid power system (MHPS). A smaller number of FOT batteries were applied in a vehicle-assigned test design where the test battery is repeatedly mounted in a unique test vehicle. Thus, vehicle category and specific driving profiles can be taken into account in multiple regression. Both parameters have only secondary influence on battery degradation, instead, extended vehicle rest time linked to low mileage performance is more serious. A tear-down analysis was accomplished for selected VRLA–AGM batteries operated in the MHPS. Clear indications are found that pSoC-operation with periodically fully charging the battery (refresh charging) does not result in sulfation of the negative electrode. Instead, the batteries show corrosion of the positive grids and weak adhesion of the positive active mass.

12/00829 Effect of electrolysis condition of zinc powder production on zinc–silver oxide battery operation

Mojtahedi, M. *et al. Energy Conversion and Management*, 2011, 52, (4), 1876–1880.
A research conducted to produce zinc powder through electrolysis of alkaline solutions by using various concentrations of KOH and zincate in the bath. Different current densities were applied for each concentration and then, morphological changes of Zn powder batches were examined by scanning electron microscopy. Afterward, an anode electrode was produced from each pack of powder. Thirty-six Zn–AgO battery cells were prepared totally. Discharge parameters of the cells were examined and time–voltage curves were analysed. Discharge times were investigated for various conditions of Zn deposition and the proper terms were suggested. It has been seen that increase of KOH concentration and decrease of zincate ion in the bath solution will change the zinc morphology and increase the resultant battery discharge time. The longest time of discharge, before reduction of cell voltage to 1.25 V, was 7.91 min. This result was obtained for Zn powder produced in zincate concentration of 0.5 M, KOH concentration of 11 M and current density of 2500 A/m^2.

12/00830 Energy use, cost and CO_2 emissions of electric cars

van Vliet, O. *et al. Journal of Power Sources*, 2011, 196, (4), 2298–2310.
This study examines the efficiency, costs and greenhouse gas emissions of current and future electric cars (EV), including the impact from charging EV on electricity demand and infrastructure for generation and distribution. Uncoordinated charging would increase national peak load by 7% at 30% penetration rate of EV and household peak load by 54%, which may exceed the capacity of existing electricity distribution infrastructure. At 30% penetration of EV, off-peak charging would result in a 20% higher, more stable base load and no additional peak load at the national level and up to 7% higher peak load at the household level. Therefore, if off-peak charging is successfully introduced, electric driving need not require additional generation capacity, even in case of 100% switch to electric vehicles. GHG emissions from electric driving depend most on the fuel type (coal or natural gas) used in the generation of electricity for charging, and range between 0 g km^{-1} (using renewables) and 155 g km^{-1} (using electricity from an old coal-based plant). Based on the generation capacity projected for the Netherlands in 2015, electricity for EV charging would largely be generated using natural gas, emitting 35–77 g $CO_{2\,eq}$ km^{-1}. The total cost of ownership (TCO) of current EV are uncompetitive with regular cars and series hybrid cars by more than 800 € $year^{-1}$. TCO of future wheel motor PHEV may become competitive when batteries cost 400 € kWh^{-1}, even without tax incentives, as long as one battery pack can last for the lifespan of the vehicle. However, TCO of future battery powered cars is at least 25% higher than of series hybrid or regular cars. This cost gap remains unless cost of batteries drops to 150 € kWh^{-1} in the future. Variations in driving cost from charging patterns have negligible influence on TCO. GHG abatement costs using plug-in hybrid cars are currently 400–1400 € $tonne^{-1}$ $CO_{2\,eq}$ and may come down to −100 to 300 € $tonne^{-1}$. Abatement cost using battery powered cars are currently above 1900 € $tonne^{-1}$ and are not projected to drop below 300–800 € $tonne^{-1}$.

12/00831 Modeling the prospects of plug-in hybrid electric vehicles to reduce CO_2 emissions

Doucette, R. T. and McCulloch, M. D. *Applied Energy*, 2011, 88, (7), 2315–2323.
This study models the CO_2 emissions from electric (EV) and plug-in hybrid electric vehicles (PHEV), and compares the results to published values for the CO_2 emissions from conventional vehicles based on internal combustion engines (ICE). PHEVs require fewer batteries than EVs which can make them lighter and more efficient than EVs. PHEVs can also operate their onboard ICEs more efficiently than can conventional vehicles. From this, it was theorized that PHEVs may be able to emit less CO_2 than both conventional vehicles and EVs given certain power generation mixes of varying CO_2 intensities. Amongst the results it was shown that with a highly CO_2 intensive power generation mix, such as in China, PHEVs had the potential to be responsible for fewer tank to wheel CO_2 emissions over their entire range than both a similar electric and conventional vehicle. The results also showed that unless highly CO_2 intensive countries pursue a major decarbonization of their power generation, they will not be able to fully take advantage of the ability of EVs and PHEVs to reduce the CO_2 emissions from automotive transport.

12/00832 Optimal charging of electric drive vehicles in a market environment

Kristoffersen, T. K. *et al. Applied Energy*, 2011, 88, (5), 1940–1948.
With a potential to facilitate the integration of renewable energy into the electricity system, electric drive vehicles may offer a considerable flexibility by allowing for charging and discharging when desired. This paper takes the perspective of an aggregator that manages the electricity market participation of a vehicle fleet and presents a framework for optimizing charging and discharging of the electric drive vehicles, given the driving patterns of the fleet and the variations in

market prices of electricity. When the aggregator is a price-taker the optimization can be stated in terms of linear programming whereas a quadratic programming formulation is required when he/she has market power. A Danish case study illustrates the construction of representative driving patterns through clustering of survey data from Western Denmark and the prediction of electricity price variations through regression on prices from the Nordic market. The results show that electric vehicles provide flexibility almost exclusively through charging. Moreover, the vehicles provide flexibility within the day but only limited flexibility from day to day when driving patterns are fixed.

12 REFRACTORIES/ CERAMICS

Properties, production, applications

12/00833 A life cycle approach to green public procurement of building materials and elements: a case study on windows

Tarantini, M. *et al. Energy*, 2011, 36, (5), 2473–2482.

Green public procurement (GPP) is a significant policy tool for reducing the environmental impacts of services and products throughout their whole life cycle. Scientific and easily verifiable environmental criteria, based on a life cycle approach, should be developed and used within procurement procedures. In this paper, life cycle assessment (LCA) is applied to wood windows showing how it can support the criteria definition. After a foreword on GPP development in Italy, the evaluation features of the environmental performances of building materials and components are outlined. The LCA case study is then presented, describing the use of the analysis results to define the environmental criteria. LCA allowed to identify the main impacts and the critical processes of the window life cycle, giving a scientific framework to discuss GPP criteria with manufacturers associations and stakeholders. Nevertheless, it could not help neither in identifying detailed criteria for GPP nor to define numerical thresholds to be used as reference in procurement procedures. The appropriate strategies should be selected taking into account the technical status of the market, the standard development and the voluntary industry commitments, involving manufacturers associations. Finally, some elements to develop a structured approach for GPP of construction materials are presented.

12/00834 Analysis and modelling of window and glazing systems energy performance for a well insulated residential building

Gasparella, A. *et al. Energy and Buildings*, 2011, 43, (4), 1030–1037.

The energy performance of a window depends on its thermal transmittance, the glazing solar transmittance, and the air leakage due to the frame and installation airtightness. In new installations air leakage represents a quite small term which is almost independent from the window and in particular from the glazing system selection. The contributions of the two other terms to the building thermal balance are not independent to each other: the most effective thermal insulating glazing, as triple glazings, are generally characterized by low solar transmittance reducing solar gains. The thermal energy balance of the building is then affected not only in summer but also in winter, potentially increasing heating energy need. This work evaluates the impact of different kinds of glazing systems (two double and two triple glazings), window size (from 16% to 41% of window to floor area ratio), orientation of the main windowed facade and internal gains on winter and summer energy need and peak loads of a well-insulated residential building. The climatic data of four localities of central and southern Europe have been considered: Paris, Milan, Nice and Rome. A statistical analysis has been performed on the results in order to identify the most influencing parameters.

12/00835 Axial two-phase thermal conductivity of ceramic sponges – experimental results and correlation

Dietrich, B. *et al. International Journal of Heat and Mass Transfer*, 2011, 54, (11–12), 2276–2282.

In this publication experimental results for the axial two-phase thermal conductivity of different ceramic sponges (variation of material, porosity and pore size) are presented, revealing a strong influence of the superficial air velocity and of the porosity of the ceramic sponges on the axial two-phase thermal conductivity. The experimental data are correlated in dimensionless form to offer a 'universal' equation for calculating the axial two-phase thermal conductivity of sponges in the future.

12/00836 Compliant alkali silicate sealing glass for solid oxide fuel cell applications: thermal cycle stability and chemical compatibility

Chou, Y.-S. *et al. Journal of Power Sources*, 2011, 196, (5), 2709–2716.

An alkali silicate glass (SCN-1) is currently being evaluated as a candidate sealing glass for solid oxide fuel cell (SOFC) applications. The glass containing ~17 mole% alkalis (K_2O and Na_2O) remains vitreous and compliant during SOFC operation, unlike conventional SOFC sealing glasses, which experience substantial devitrification after the sealing process. The non-crystallizing compliant sealing glass has lower glass transition and softening temperatures since the microstructure remains glassy without significant crystallite formation, and hence can relieve or reduce residual stresses and also has the potential for crack healing. Sealing approaches based on compliant glass will also need to satisfy all the mechanical, thermal, chemical, physical, and electrical requirements for SOFC applications, not only in bulk properties but also at sealing interfaces. In this first of a series of papers the authors will report the thermal cycle stability of the glass when sealed between two SOFC components, i.e. a NiO/YSZ anode supported YSZ bilayer and a coated ferritic stainless steel interconnect material. High temperature leak rates were monitored versus thermal cycles between 700 and 850 °C using back pressures ranging from 1.4 to 6.8 kPa (0.2–1.0 psi). Isothermal stability was also evaluated in a dual environment consisting of flowing dilute H_2 fuel versus ambient air. In addition, chemical compatibility at the alumina and YSZ interfaces was examined with scanning electron microscopy and energy dispersive spectroscopy. The results shed new light on the topic of SOFC glass seal development.

12/00837 Coupled radiation and flow modeling in ceramic foam volumetric solar air receivers

Wu, Z. *et al. Solar Energy*, 2011, 85, (9), 2374–2385.

Ceramic foams are promising materials for the absorber of volumetric solar air receivers in concentrated solar thermal power (CSP) receivers. The macroscopic temperature distribution in the volumetric solar air receiver is crucial to guarantee that volumetric solar air receivers work steadily, safely and above all, efficiently. This study analyses the temperature distribution of the fluid and solid phases in volumetric solar air receivers. The pressure drop in the ceramic foams and the interfacial heat transfer between the flowing fluid and solid are included in the model. The radiative heat transfers due to concentrated solar radiation absorption by the ceramic foam and the radiation transport in the media were modelled with the P_1 approximation. The energy fields of the fluid and solid phases were obtained using the local thermal non-equilibrium model (LTNE). Comparison of the macroscopic model with experimental results shows that the macroscopic model can be used to predict the performance of solar air receivers. Sensitivity studies were conducted to analyse the effects of velocity, porosity, mean cell size and the thermal conductivity of the solid phase on the temperature fields. The results illustrate that the thermal non-equilibrium phenomena are locally important, and the mean cell size has a dominant effect on the temperature field.

12/00838 Cyclic stability and C-rate performance of amorphous silicon and carbon based anodes for electrochemical storage of lithium

Ahn, D. and Raj, R. *Journal of Power Sources*, 2011, 196, (4), 2179–2186.

Polymer-derived, amorphous ceramics (PDCs) constituted from silicon, carbon, oxygen and nitrogen are promising candidates as anodes for lithium ion (Li^+) batteries, having a reversible capacity of up to 800 mAh g^{-1}. These measurements of lithium capacity are extended here to cyclic stability, high C-rate performance, and composition-range. The following new results are presented: (a) materials processed at 800 °C perform better than those synthesized at lower and higher temperatures, (b) materials with high oxygen content perform better than those with high nitrogen, (c) the SiCO materials are highly stable in cyclic loading, and (d) they are robust materials, capable of very high C-rates, without damage to their overall performance. Phenomenological analysis of composition dependent capacity suggests that Li is sequestered to mixed-bond tetrahedra of Si coordinated to both oxygen and carbon; it is argued that when oxygen is substituted by nitrogen the ability of these mixed bonds to bind to lithium in a reversible manner is severely diminished.

12/00839 Moisture buffering performance of a new pozolanic ceramic material: influence of the film layer resistance

Gómez, I. *et al. Energy and Buildings*, 2011, 43, (4), 873–878.

One of the variables that has a greater influence on the determination of the moisture buffering capacity of a material to be used as inner surface layer of an enclosure is the value of the vapour resistance of the surface film layer. In this paper, the influence of such a surface resistance on the moisture buffering value (MBV) is studied by means of a small experimental equipment where the tests were developed according to the NordTest protocol, but modifying the air speed over the samples, in order to take in count its influence. The tested material is an autoclaved ceramic made from the shells of the molluscs grown in Brazil, with the aim of using it as indoor surface layer of the enclosures in museums and buildings used to keep archives and documents, and where it is required to control the conditions of the indoor air by means of passive systems based on the moisture buffering capacity of the materials. The theoretical MBV is determined too based on the effusivity of the material which is obtained from its basic hygroscopic characterization.

12/00840 Nanostructure Cu_2ZnSnS_4 thin film prepared by sol–gel for optoelectronic applications

Yakuphanoglu, F. *Solar Energy*, 2011, 85, (10), 2518–2523.

Thin film of Cu_2ZnSnS_4 (CZTS) has been successfully deposited by sol–gel technique on n-type silicon and glass substrates to fabricate a heterojunction photodiode. The structural properties of the film were investigated by atomic force microscopy. The AFM image of the Cu_2ZnSnS_4 film reveals that the film is a nanostructure material formed from nanoparticles with the particle size of 50–90 nm. The optical band gap, E_g of the Cu_2ZnSnS_4 film was found to be 1.48 eV and the obtained optical band gap suggests that CZTS is very suitable for photovoltaic and optoelectronic applications. The current–voltage characteristics of the Al/n-Si/Cu_2ZnSnS_4/Al diode exhibit a good rectification behaviour with ideality factor of 2.84 and barrier height of 0.738 eV. The interface states of the diode were analysed by series resistance and conductance-voltage methods. The presence of interface states in series resistance–voltage plots was confirmed by the illumination. The interface state density D_{it} for the diode was found to be $3.63 \times 10^{12}\,eV^{-1}\,cm^{-2}$. The obtained results indicate that the Al/n-Si/Cu_2ZnSnS_4/Al diode is a photosensor based on controlling of interface states by illumination.

12/00841 Optimization of insulation thickness for different glazing areas in buildings for various climatic regions in Turkey

Özkan, D. B. and Onan, C. *Applied Energy*, 2011, 88, (4), 1331–1342.

Insulation is one of the most effective methods intended for reducing energy consumption in both heating and cooling of buildings. Selecting the right materials and determining the optimum insulation thickness in building insulation application is an important issue. In 2000, the 'Thermal insulation requirements for buildings' was enacted in Turkey, energy saving by limiting the energy amount used for heating in buildings being the target. In this study, the effect of the alteration of windows and exterior wall areas on the heating energy requirement of the building and on the optimum insulation thickness has been examined by using P_1–P_2 method. The study has been carried out for four degree-day regions of Turkey for various insulation materials, glazing areas, and fuel types; the results have been presented in charts. In the rest of this study, effects of different insulation thicknesses and fuel on fuel consumption and thereby on emissions of pollutants such as CO_2 and SO_2 are evaluated. For example, in the building where XPS (extruded polystyrene foam) insulation material and natural gas are used and where the ratio of glazing area to exterior wall area is 0.2 (glazing area percentage), energy saving for the four regions has been found to be 13.996, 31.680, 46.613, and 63.071 $/m^2, respectively, and the payback period of investment has been found to be 2.023, 1.836, 1.498, and 1.346 years, respectively. The emissions of CO_2 are decreased by 50.91% for the cases in which optimum insulation material and natural gas are used. The emissions of CO_2 and SO_2 are decreased by 54.67% for the cases in which optimum insulation material (XPS) and fuel oil are used.

12/00842 Revisiting the block method for evaluating thermal conductivities of clay and granite

Akinyemi, O. D. *et al. International Communications in Heat and Mass Transfer*, 2011, 38, (8), 1014–1018.

Determination of thermal conductivities of porous media using the contact method was revisited and revalidated. Thermal conductivities of granite and clay were determined in the laboratory with and without the use of thermal interface material (TIM) (Arctic Silver®) to reduce contact resistance. KD2 probe was also used with and without TIM to compare results. Thermal conductivity of dry clay sample increased from 0.68 to 0.85 W/mK while that of granite sample increased from 2.95 to 3.95 W/mK with TIM. The difference in thermal conductivities with and without TIM was significant at ($P > 0.05$).

12/00843 Study of geometric stability and structural integrity of self-healing glass seal system used in solid oxide fuel cells

Liu, W. N. *et al. Journal of Power Sources*, 2011, 196, (4), 1750–1761.

A self-healing glass seal has the potential to restore its mechanical properties upon being reheated to the solid oxide fuel cell (SOFC) stack operating temperature. Such a self-healing feature is desirable for achieving high seal reliability during thermal cycling. Self-healing glass is also characterized by its low mechanical stiffness and high creep rate at SOFC operating temperatures. Therefore, the geometric stability and structural integrity of the glass seal system are critical to its successful application in SOFCs. This paper describes studies of the geometric stability and structural integrity of the self-healing glass seal system and the influence of various interfacial conditions during the operating and cooling-down processes using finite element analyses. For this purpose, the test cell used in the leakage tests for compliant glass seals, conducted at Pacific Northwest National Laboratory (PNNL), was taken as the initial modelling geometry. The effect of the ceramic stopper on the geometric stability of the self-healing glass sealants was studied first. Two interfacial conditions of the ceramic stopper and glass seals, i.e. bonded (strong) or unbonded (weak), were considered. Then the influences of interfacial strengths at various interfaces, i.e. stopper/glass, stopper/PEN, as well as stopper/IC plate, on the geometric stability and reliability of glass during the operating and cooling processes were examined.

12/00844 Ultrasound aided *in situ* transesterification of crude palm oil adsorbed on spent bleaching clay

Boey, P.-L. *et al. Energy Conversion and Management*, 2011, 52, (5), 2081–2084.

Adsorbed crude palm oil on spent bleaching clay (SBC) was *in situ* transesterified to methyl esters (biodiesel) by the aid of ultrasound and organic co-solvents [petroleum ether (PE) or ethyl methyl ketone (EMK)]. The SBC under study was found to contain 24.2–27.0% of crude oil with free fatty acids (FFA) of 3.01% and moisture content of 0.29%. The optimized reaction conditions were as follows: methanol to oil molar ratio of 150:1; catalyst (KOH), 20%; reaction temperature, $60 \pm 2\,^{\circ}C$; reaction time, 2 h. Using PE as a co-solvent, highest conversion of 75.2% was achieved while 60% was recorded with EMK.

13 ALTERNATIVE ENERGY SUPPLIES

Biofuels and bioconversion energy

12/00845 Assessing the potential for the uptake of on-farm anaerobic digestion for energy production in England

Tranter, R. B. *et al. Energy Policy*, 2011, 39, (5), 2424–2430.

This study reports on an assessment of the potential for energy production from on-farm anaerobic digestion (AD) in England based on findings from a survey of farmers where it was found that around 40% of 381 respondents might install AD on their farms. These 'possible adopters' tended to have large farms and might together utilize some 6560 ha of land for feedstock production along with the wastes from some 12,000 beef and dairy cattle and 9000 pigs. When raised to the national level, such a level of AD activity would produce around 3.5 GWh of electricity. This approximates to just 0.001% of national electricity generation. Further, there are considerable perceived barriers to the widespread adoption of AD on farms in England; these include the high capital costs of installing AD and doubts about the economic returns being high enough.

12/00846 Assessment on the use of biodiesel in cold weather: pour point determination using a piezoelectric quartz crystal

Veríssimo, M. I. S. and Gomes, M. T. S. R. *Fuel*, 2011, 90, (6), 2315–2320.

In order to use biodiesel safely, as an alternative fuel for diesel engines, without fear of cold weather, the pour point of the blends needs to be estimated. This paper is aimed to propose an alternative and easy to use methodology, based on a piezoelectric quartz crystal, to determine the pour point of biodiesels and blended fuels. Impedance and phase of impedance versus frequency of the piezoelectric quartz crystal change significantly during cooling of biodiesel and biodiesel blended fuels and allows to confirm the role of ethanol as a cold flow improver for biodiesel. Pour point is readily determined by finding the minimum

series or parallel frequencies of a barred piezoelectric quartz crystal in contact with the biodiesel blended fuel along cooling. This new methodology only needs the measurement of series frequency, which can be accomplished with high precision by connecting a frequency meter to a home-made oscillator that drives the piezoelectric quartz crystal. Although inexpensive, this new methodology is no more based on visual inspection as the ASTM D97 method, and allows data to be acquired more frequently than the 3 °C intervals recommended by the time consuming standard methodology. In the new proposed methodology, data is acquired while the fuel is at the controlled temperature, which is not possible with the ASTM method, where the test jar needs to be removed from the thermostatic bath for visual inspection. Pour points of biodiesel blends with a commercial diesel fuel determined by this new methodology were compared with the ones obtained by the official ASTM methodology. For samples with pour points ranging from 2.3 °C (pure biodiesel) to −15.0 °C (pure commercial fuel diesel), median pour point values obtained for replicate measurements performed by the two methodologies were not statistically different ($\alpha = 0.05$), although the results obtained by the new methodology were more precise.

12/00847 Biocatalytic production of biodiesel from cottonseed oil: standardization of process parameters and comparison of fuel characteristics

Chattopadhyay, S. *et al. Applied Energy*, 2011, 88, (4), 1251–1256.

The enzymatic production of biodiesel by transesterification of cottonseed oil was studied using low cost crude pancreatic lipase as catalyst in a batch system. The effects of the critical process parameters including water percentage, methanol:oil ratio, enzyme concentration, buffer pH and reaction temperature were determined. Maximum conversion of 75–80% was achieved after 4 h at 37 °C, pH 7.0 and with 1:15 M ratio of oil to methanol, 0.5% (wt of oil) enzyme and water concentration of 5% (wt of oil). Various organic solvents were tested among which a partially polar solvent (*t*-butanol) was found to be suitable for the reaction. The major fuel characteristics like specific gravity, kinematic viscosity, flash point and calorific value of the 20:80 blends (B20) of the fatty acid methyl esters with petroleum diesel conformed very closely to those of American Society for Testing Materials (ASTM) standards.

12/00848 Biodiesel production from mixed soybean oil and rapeseed oil

Qiu, F. *et al. Applied Energy*, 2011, 88, (6), 2050–2055.

The biodiesel (fatty acid methyl esters, FAME) was prepared by transesterification of the mixed oil (soybean oil and rapeseed oil) with sodium hydroxide (NaOH) as catalyst. The effects of mole ratio of methanol to oil, reaction temperature, catalyst amount and reaction time on the yield were studied. In order to decrease the operational temperature, a co-solvent (hexane) was added into the reactants and the conversion efficiency of the reaction was improved. The optimal reaction conditions were obtained by this experiment: methanol/oil mole ratio 5.0:1, reaction temperature 55 °C, catalyst amount 0.8 wt% and reaction time 2.0 h. Under the optimum conditions, a 94% yield of methyl esters was reached ∼94%. The structure of the biodiesel was characterized by FT-IR spectroscopy. The sulfur content of biodiesel was determined by inductively coupled plasma emission spectrometry, and the satisfied result was obtained. The properties of obtained biodiesel from mixed oil are close to commercial diesel fuel and is rated as a realistic fuel as an alternative to diesel. Production of biodiesel has positive impact on the utilization of agricultural and forestry products.

12/00849 Biogas purification for MCFC application

Hernández, S. P. *et al. International Journal of Hydrogen Energy*, 2011, 36, (13), 8112–8118.

Biogas from landfills is a powerful renewable fuel that can be used as a feedstock for fuel cell systems. However, it has to be purified of sulfur compounds and halogenated species, which are poisonous for both fuel cells and reforming catalysts. This work presents a benchmarking study on the removal of sulfur and halogenated compounds from a model landfill biogas through adsorption. Six commercial adsorbents have been tested to compare their selectivity and their uptake capacity towards nine different sulfur compounds. A multi-step adsorption process, characterized by a high adsorptive-capacity and rather low costs has been proposed. Two specific activated carbons for the removal of halogenated species have also been tested for the purification of nine chlorinated hydrocarbons that are present in the model biogas. One single system that could completely eliminate the halogenated molecules contained in the biogas could not be found, which indicates the necessity of specific developments.

12/00850 Bio-hydrogen production by different operational modes of dark and photo-fermentation: an overview

Argun, H. and Kargi, F. *International Journal of Hydrogen Energy*, 2011, 36, (13), 7443–7459.

This article overviews reported studies on bio-hydrogen production from different raw materials by dark and photo-fermentations operated with different modes. Sequential and combined dark and photo-fermentations operated in batch, continuous and fed-batch modes were compared. Operating conditions and modes resulting in the highest hydrogen yield and formation rate were revealed. Relative advantages of sequential and combined dark and photo-fermentations were discussed. Sequential fermentation was found to be preferable due to high H_2 yields and productivities. High cell density fed-batch culture with controlled feeding and simultaneous product removal was concluded to be the most suitable operation mode at the optimum environmental conditions.

12/00851 Boundary estimation of hyperbolic bio-heat conduction

Yang, C.-y. *International Journal of Heat and Mass Transfer*, 2011, 54, (11–12), 2506–2513.

A sequential method is proposed for estimating the boundary condition in hyperbolic bio-heat conduction. The estimated solution is deduced from a numerical approach combined with the concept of future time. The problem with inverse bio-heat conduction is the slow heat-wave propagation speed, resulting in no temperature measurements obtained. Three cases are presented to demonstrate the features and the validity of the proposed method. Comparison between the exact value and the estimated result is made to confirm the validity and accuracy of the proposed method.

12/00852 CO_2 capture and storage from a bioethanol plant: carbon and energy footprint and economic assessment

Laude, A. *et al. International Journal of Greenhouse Gas Control*, 2011, 5, (5), 1220–1231.

Biomass energy and carbon capture and storage (BECCS) can lead to a net removal of atmospheric CO_2. This paper investigates environmental and economic performances of CCS retrofit applied to two mid-sized refineries producing ethanol from sugar beets. Located in the Region Centre France, each refinery has two major CO_2 sources: fermentation and cogeneration units. 'Carbon and energy footprint' (CEF) and 'discounted cash flow' (DCF) analyses show that such a project could be a good opportunity for CCS early deployment. CCS retrofit on fermentation only with natural gas fired cogeneration improves CEF of ethanol production and consumption by 60% without increasing much the non-renewable energy consumption. CCS retrofit on fermentation and natural gas fired cogeneration is even more appealing by decreasing of 115% CO_2 emissions, while increasing non-renewable energy consumption by 40%. DCF shows that significant project rates of return can be achieved for such small sources if both a stringent carbon policy and direct subsidies corresponding to 25% of necessary investment are assumed. It is also underlined that transport and storage cost dilution can be realistically achieved by clustering emissions from various plants located in the same area. On a single plant basis, increasing ethanol production can also produce strong economies of scale.

12/00853 Characterization and prediction of biomass pyrolysis products

Neves, D. *et al. Progress in Energy and Combustion Science*, 2011, 37, (5), 611–630.

In this study literature data on the pyrolysis characteristics of biomass under inert atmosphere were structured and analysed, constituting a guide to the conversion behaviour of a fuel particle within the temperature range of 200–1000 °C. Data are presented for both pyrolytic product distribution (yields of char, total liquids, water, total gas and individual gas species) and properties (elemental composition and heating value) showing clear dependencies on peak temperature. Empirical relationships are derived from the collected data, over a wide range of pyrolysis conditions and considering a variety of fuels, including relations between the yields of gas-phase volatiles and thermochemical properties of char, tar and gas. An empirical model for the stoichiometry of biomass pyrolysis is presented, where empirical parameters are introduced to close the conservation equations describing the process. The composition of pyrolytic volatiles is described by means of a relevant number of species: H_2O, tar, CO_2, CO, H_2, CH_4 and other light hydrocarbons. The model is here primarily used as a tool in the analysis of the general trends of biomass pyrolysis, enabling also to verify the consistency of the collected data. Comparison of model results with the literature data shows that the information on product properties is well correlated with the one on product distribution. The prediction capability of the model is briefly addressed, with the results showing that the yields of volatiles released from a specific biomass are predicted with a reasonable accuracy. Particle models of the type presented in this study can be useful as a submodel in comprehensive reactor models simulating pyrolysis, gasification or combustion processes.

12/00854 Characterization and transesterification of Iranian bitter almond oil for biodiesel production

Atapour, M. and Kariminia, H.-R. *Applied Energy*, 2011, 88, (7), 2377–2381.

In the present work the production of biodiesel using bitter almond oil (BAO) in a potassium hydroxide catalysed transesterification reaction was investigated. The BAO was obtained from resources available in Iran and its physical and chemical properties including iodine value, acid value, density, kinematic viscosity, fatty acid composition and mean molecular weight were specified. The low acid value of BAO (0.24 mg KOH/g) indicated that the pretreatment of raw oil with acid was not required. The fatty acid content analysis confirmed that the contribution of unsaturated fatty acids in the BAO is high (84.7 wt%). Effect of different parameters including methanol to oil molar ratio (3–11 mol/mol), potassium hydroxide concentration (0.1–1.7% w/w) and reaction temperature (30–70 °C) on the production of biodiesel were investigated. The results indicated that these parameters were important factors affecting the tranesterification reaction. The fuel properties of biodiesel including iodine value, acid value, density, kinematic viscosity, saponification value, cetane number, flash point, cloud point, pour point and distillation characteristics were measured. The properties were compared with those of petroleum diesel, EN 14214 and ASTM 6751 biodiesel standards and an acceptable agreement was observed.

12/00855 Comparison of slow and vacuum pyrolysis of sugar cane bagasse

Carrier, M. *et al. Journal of Analytical and Applied Pyrolysis*, 2011, 90, (1), 18–26.

Experimental results for slow and vacuum pyrolysis of sugar cane bagasse, in the same reactor allowing the comparison of these two processes, are reported. The experimental results showed that vacuum pyrolysis leads to a higher BET specific surface area whereas slow pyrolysis seemed to favour the HHV of charcoal. Detailed yields of products are presented and the influence of temperature and heating rate were studied using a design of experiments and an ANOVA analysis. From the results the optimum experimental conditions to maximize the yields of char and bio-oil products, as well as their heating value and specific surface area characteristics, were established. The optimal yields of bio-oil for vacuum pyrolysis were obtained at 400–500 °C and a heating rate of 15–24 °C min^{-1}, and for char the corresponding values are 340–350 °C and 18–24 °C min^{-1}. Slow pyrolysis produced the highest char yield. The optimal ranges of temperature and heating rate differ from that of vacuum pyrolysis mainly due to the short residence time of the vapours in the case of vacuum pyrolysis. Optimum conditions for bio-oil and char yields did not correspond with conditions to optimize the BET surface and HHV for chars, and to minimize the water content of the products.

12/00856 Ethanol demand in Brazil: regional approach

de Freitas, L. C. and Kaneko, S. *Energy Policy*, 2011, 39, (5), 2289–2298.

Successive studies attempting to clarify national aspects of ethanol demand have assisted policy makers and producers in defining strategies, but little information is available on the dynamic of regional ethanol markets. This study aims to analyse the characteristics of ethanol demand at the regional level taking into account the peculiarities of the developed centre–south and the developing north–north-east regions. Regional ethanol demand is evaluated based on a set of market variables that include ethanol price, consumer's income, vehicle stock and prices of substitute fuels; i.e. gasoline and natural gas. A panel cointegration analysis with monthly observations from January 2003 to April 2010 is employed to estimate the long-run demand elasticity. The results reveal that the demand for ethanol in Brazil differs between regions. While in the centre–south region the price elasticity for both ethanol and alternative fuels is high, consumption in the north–north-east is more sensitive to changes in the stock of the ethanol-powered fleet and income. These, among other evidences, suggest that the pattern of ethanol demand in the centre–south region most closely resembles that in developed nations, while the pattern of demand in the north–north-east most closely resembles that in developing nations.

12/00857 How can we improve biomethane production per unit of feedstock in biogas plants?

Asam, Z.u-Z. *et al. Applied Energy*, 2011, 88, (6), 2013–2018.

Biogas production is one of the number of tools that may be used to alleviate the problems of global warming, energy security and waste management. Biogas plants can be difficult to sustain from a financial perspective. The facilities must be financially optimized through use of substrates with high biogas potential, low water content and low retention requirement. This research carried out in laboratory scale batch digesters assessed the biogas potential of energy crops (maize and grass silage) and solid manure fractions from manure separation units. The ultimate methane productivity in terms of volatile solids (VS) was determined as 330, 161, 230, 236, 361 L/kg VS from raw pig slurry, filter pressed manure fibre (FPMF), chemically precipitated manure fibre (CPMF), maize silage and grass silage respectively. Methane productivity based on mass (L/kg substrate) was significantly higher in FPMF (55 L/kg substrate), maize silage (68 L/kg substrate) and grass silage (45–124 L/kg substrate (depending on dry solids of feedstock)) as in comparison to raw pig slurry (10 L/kg substrate). The use of these materials as co-substrates with raw pig slurry will increase significantly the biomethane yield per unit feedstock in the biogas plant.

12/00858 Improving energy use efficiency of canola production using data envelopment analysis (DEA) approach

Mousavi-Avval, S. H. *et al. Energy*, 2011, 36, (5), 2765–2772.

In this study energy use pattern for canola production in Golestan province of Iran was studied and the degrees of technical and scale efficiency of producers were analysed using a non-parametric data envelopment analysis technique. The study also helped to identify the wasteful uses of energy by inefficient farmers and to suggest reasonable savings in energy uses from different inputs. Further, the effect of optimization of energy on energy ratio and energy productivity was investigated. Data used in this study were obtained from 130 randomly selected canola farms from Golestan, the most important centre of canola production in Iran. The inputs were human labour, diesel, machinery, fertilizers, chemicals, water for irrigation, seeds and electrical energies; while the yield value of canola was considered as output. The results revealed that, the total energy of 17,786 MJ ha^{-1} was consumed for canola production; about 15% of farmers were found to be technically efficient and the mean efficiency of farmers was found to be 0.74 and 0.88 under constant and variable returns to scale assumptions, respectively. The results also suggested that, on average, a potential 9.5% (1696 MJ ha^{-1}) reduction in total energy input could be achieved provided that all farmers operated efficiently.

12/00859 Influence of the interaction of components on the pyrolysis behavior of biomass

Wang, S. *et al. Journal of Analytical and Applied Pyrolysis*, 2011, 91, (1), 183–189.

There has been much interest in the utilization of biomass-derived fuels as substitutes for fossil fuels in meeting renewable energy requirements to reduce CO_2 emissions. In this study, the pyrolysis characteristics of biomass have been investigated using both a thermogravimetric analyser coupled with a Fourier-transform infrared spectrometer (TG-FTIR) and an experimental pyrolyser. Experiments have been conducted with the three major components of biomass, i.e. hemicellulose, cellulose, and lignin, and with four mixed biomass samples comprising different proportions of these. Product distributions in terms of char, bio-oil, and permanent gas are given, and the compositions of the bio-oil and gaseous products have been analysed by gas chromatography–mass spectrometry (GC–MS) and gas chromatography (GC). The TG results show that the thermal decomposition of levoglucosan is extended over a wider temperature range according to the interaction of hemicellulose or lignin upon the pyrolysis of cellulose; the formation of 2-furfural and acetic acid is enhanced by the presence of cellulose and lignin in the range 350–500 °C; and the amount of phenol, 2,6-dimethoxy is enhanced by the integrated influence of cellulose and hemicellulose. The components do not act independently during pyrolysis; the experimental results have shown that the interaction of cellulose and hemicellulose strongly promotes the formation of 2,5-diethoxytetrahydrofuran and inhibits the formation of altrose and levoglucosan, while the presence of cellulose enhances the formation of hemicellulose-derived acetic acid and 2-furfural. Pyrolysis characteristics of biomass cannot be predicted through its composition in the main components.

12/00860 MSW landfill biogas desulfurization

Mescia, D. *et al. International Journal of Hydrogen Energy*, 2011, 36, (13), 7884–7890.

Biogas utilization in MCFC systems requires a high level of gas purification in order to meet the stringent sulfur tolerance limits of both the fuel cells and the reformer catalysts. In this study, two commercial activated carbons (ACs) have been tested for H_2S removal from the biogas produced at the Montescarpino Municipal Solid Waste landfill in Genoa, Italy. The performed analyses show a low selectivity of activated carbon towards the adsorption of only sulfur species. This represents a drawback for the use of this type of system, however, the use of mixed beds of different ACs has demonstrated to be advantageous in improving the removal efficiency of H_2S. Thus, the adsorption treatments with AC can ensure the high level of gas desulfurization required for fuel cell application. Nevertheless, the low adsorption capacity observed using landfill biogas would lead to high operative costs that suggest the application of a preliminary gas-scrubbing stage.

12/00861 Premium quality renewable diesel fuel by hydroprocessing of sunflower oil

Šimáček, P. *et al. Fuel*, 2011, 90, (7), 2473–2479.

Hydroprocessing of neat sunflower oil was carried out at 360–420 °C and 18 MPa over a commercial hydrocracking catalyst in a bench scale fixed bed reactor. In the studied experimental range, products consisted exclusively of hydrocarbons that differed significantly in composition. While the concentration of n-alkanes exceeded 67 wt% in the reaction products collected at 360 °C, it decreased to just 20 wt% in the product obtained at 420 °C. Consequently, the fuel properties of the latter product were very similar to those of standard (petroleum-derived) diesel fuel. Particularly, it exhibited excellent low-temperature properties (cloud point −11 °C; CFPP −14 °C). Reaction products obtained at 400 and 420 °C were blended into petroleum-derived diesel fuel in three concentration levels ranging from 10 to 50 wt% and the fuel properties of these mixtures were evaluated. Diesel fuel mixtures containing the product of sunflower oil hydrocracking at 420 °C showed very good low-temperature properties including cloud point (−8 °C) and CFPP (−15 °C) that was further lowered to −25 °C due to addition of flow improvers.

12/00862 Techniques for transformation of biogas to biomethane

Ryckebosch, E. *et al. Biomass and Bioenergy*, 2011, 35, (5), 1633–1645.

Biogas from anaerobic digestion and landfills consists primarily of CH_4 and CO_2. Trace components that are often present in biogas are water vapour, hydrogen sulfide, siloxanes, hydrocarbons, ammonia, oxygen, carbon monoxide and nitrogen. In order to transfer biogas into biomethane, two major steps are performed: (1) a cleaning process to remove the trace components and (2) an upgrading process to adjust the calorific value. Upgrading is generally performed in order to meet the standards for use as vehicle fuel or for injection in the natural gas grid. Different methods for biogas cleaning and upgrading are used. They differ in functioning, the necessary quality conditions of the incoming gas, the efficiency and their operational bottlenecks. Condensation methods (demisters, cyclone separators or moisture traps) and drying methods (adsorption or absorption) are used to remove water in combination with foam and dust. A number of techniques have been developed to remove H_2S from biogas. Air dosing to the biogas and addition of iron chloride into the digester tank are two procedures that remove H_2S during digestion. Techniques such as adsorption on iron oxide pellets and absorption in liquids remove H_2S after digestion. Subsequently, trace components like siloxanes, hydrocarbons, ammonia, oxygen, carbon monoxide and nitrogen can require extra removal steps, if not sufficiently removed by other treatment steps. Finally, CH_4 must be separated from CO_2 using pressure swing adsorption, membrane separation, physical or chemical CO_2-absorption.

12/00863 TGA and macro-TGA characterisation of biomass fuels and fuel mixtures

Skreiberg, A. *et al. Fuel*, 2011, 90, (6), 2182–2197.

The thermal behaviour of selected biomass fuels and mixtures as wood, demolition wood, coffee waste and glossy paper was investigated using a thermogravimetric analyser (TGA) and a macro-thermobalance (macro-TGA). A kinetic model, involving first-order independent parallel reactions, was applied to results obtained from pyrolysis TGA experiments. The pyrolysis rate was considered as the sum of the main biomass pseudo-components, namely cellulose, hemicellulose and lignin. Additionally, the thermal behaviour of the same fuels was investigated at combustion conditions in the TGA, including ignition behaviour. The thermogravimetric analysis showed that each single fuel had pyrolysis and combustion characteristics based on its own main pseudo-components (hemicellulose, cellulose and lignin). The pyrolysis and combustion characteristics of selected fuel mixtures and the gas composition analysis from macro-TGA experiments showed respectively quantitative and qualitative summative behaviour based on the single fuels.

12/00864 The GHG balance of biofuels taking into account land use change

Lange, M. *Energy Policy*, 2011, 39, (5), 2373–2385.

The contribution of biofuels to the saving of greenhouse gas (GHG) emissions has recently been questioned because of emissions resulting from land use change (LUC) for bioenergy feedstock production. This study investigates how the inclusion of the carbon effect of LUC into the carbon accounting framework, as scheduled by the European Commission, impacts on land use choices for an expanding biofuel feedstock production. The authors first illustrate the change in the carbon balances of various biofuels, using methodology and data from the IPCC Guidelines for National Greenhouse Gas Inventories. It becomes apparent that the conversion of natural land, apart from grassy savannahs, impedes meeting the EU's 35% minimum emissions reduction target for biofuels. They show that the current accounting method mainly promotes biofuel feedstock production on former cropland, thus increasing the competition between food and fuel production on the currently available cropland area. The authors further discuss whether it is profitable to use degraded land for commercial bioenergy production as requested by the European Commission to avoid undesirable LUC and conclude that the current regulation provides little incentive to use such land. The exclusive consideration of LUC for bioenergy production minimizes direct LUC at the expense of increasing indirect LUC.

12/00865 Thermal self-sustainability of biochar production by pyrolysis

Xu, R. *et al. Journal of Analytical and Applied Pyrolysis*, 2011, 91, (1), 55–66.

The pyrolysis of several agricultural and biofuel production residues (grape residues, sugarcane residues, dried distiller's grain, palm oil residues, apple pomace and forestry residue) has been carried out in a pilot bubbling fluidized bed pyrolyser operating under a range of temperature from 300 to 600 °C and two vapour residence times (2 and 5 s), with the aim of determining their pyrolysis behaviour including products yields and heat balance. The composition of the product gases was determined, from which their heating value was calculated. The liquid bio-oil was recovered with cyclonic condensers. The thermal sustainability of the pyrolysis process was estimated by considering the energy contribution of the product gases and of the liquid bio-oil in relation to the pyrolysis heat requirements. The most promising biomass feedstocks for the sustainable production of biochar were indentified. Furthermore, this study presented the char yield in relation to the excess heat that could be obtained by combusting the gas and bio-oil coproducts of biochar production, as functions of pyrolysis temperature and vapour residence time.

12/00866 Utilization of waste cockle shell (*Anadara granosa*) in biodiesel production from palm olein: optimization using response surface methodology

Boey, P.-L. *et al. Fuel*, 2011, 90, (7), 2353–2358.

The cockle shell, which is available in abundance, has no any eminent use and is commonly regarded as a waste, was utilized as a source of calcium oxide in catalysing a transesterification reaction to produce biodiesel (methyl esters). A central composite design (CCD) was used to optimize the two major influential reaction variables: catalyst and methanol amount towards purity and yield of methyl esters. The analysis of variance (ANOVA) indicated that the catalyst has a positive influence on purity but negative on the yield. Meanwhile, the methanol/oil mass ratio showed a positive effect on both purity and yield. Using CCD, the optimum reaction conditions were found to be 4.9 wt% of catalyst and 0.54:1 methanol/oil mass ratio. The prepared catalyst was capable of being reused under the suggested optimal conditions.

12/00867 Utilization possibilities of palm shell as a source of biomass energy in Malaysia by producing bio-oil in pyrolysis process

Abnisa, F. *et al. Biomass and Bioenergy*, 2011, 35, (5), 1863–1872.

Agriculture residues such as palm shell are one of the biomass categories that can be utilized for conversion to bio-oil by using pyrolysis process. Palm shells were pyrolysed in a fluidized-bed reactor at 400, 500, 600, 700 and 800 °C with N_2 as carrier gas at flow rate 1, 2, 3, 4 and 5 L/min. The objective of the present work is to determine the effects of temperature, flow rate of N_2, particle size and reaction time on the optimization of production of renewable bio-oil from palm shell. According to this study the maximum yield of bio-oil (47.3 wt%) can be obtained, working at the medium level for the operation temperature (500 °C) and 2 L/min of N_2 flow rate at 60 min reaction time. Temperature is the most important factor, having a significant positive effect on yield product of bio-oil. The oil was characterized by Fourier transform infrared spectroscopy and gas chromatography/mass spectrometry techniques.

12/00868 Visible and NIR spectroscopy to assess biodiesel quality: determination of alcohol and glycerol traces

Dorado, M. P. *et al. Fuel*, 2011, 90, (6), 2321–2325.

Biodiesel quality control is of relevant importance as biodiesel properties influence diesel engine performance. In the present work, the benefits of the use of visible and near-infrared spectroscopy (NIRS) as a technique for screening undesirable contaminants, i.e. methanol and glycerol content in biodiesel are presented. Excess of methanol decreases heating value and flash point and increases carbon deposits, while the presence of glycerol may cause injector tip coking and deposits in the combustion chamber. Biodiesel samples contaminated with different amounts of methanol and glycerol were scanned by NIRS. Their NIR spectra were acquired at 2-nm intervals over a wavelength range from 400 to 2500 nm (visible plus near-infrared regions). First derivatives of the spectra were calculated and correlated to the raw optical data by means of modified partial least-squares (MPLS) regression. First derivative equation of the optical data, pretreated by standard normal variate (SNV) and de-trending (DT)

transformations, showed a coefficient of determination r^2 in the cross-validation step of 0.99 and 0.81, for the samples contaminated with methanol and glycerol, respectively. Also, the standard deviation to standard error of cross-validation ratio (RPD) was 10.0 and 2.5, respectively. These statistics are indicative of the high capacity of prediction of the equations for methanol content and acceptable for glycerol content. Visible spectra also showed differences related to the samples, thus indicating it could serve to determine the presence of these contaminants. The use of NIRS technology provides a trustworthy and low-cost method to determine the presence of undesirable amounts of methanol and glycerol. It also offers an important saving of time (each analysis requires less than 2 minutes).

Geothermal energy

12/00869 An integrated control method for a wind farm to reduce frequency deviations in a small power system

Kaneko, T. *et al. Applied Energy*, 2011, 88, (4), 1049–1058.

Output power of wind turbine generator (WTG) is not constant and fluctuates due to wind speed changes. To reduce the adverse effects of the power system introducing WTGs, there are several published reports on output power control of WTGs detailing various researches based on pitch angle control, variable speed wind turbines, energy storage systems, and so on. In this context, this paper presents an integrated control method for a wind farm to reduce frequency deviations in a small power system. In this study, the wind farm achieves the frequency control with two control wind farms: load estimation and short-term ahead wind speed prediction. For load estimation in the small power system, a minimal-order observer is used as disturbance observer. The estimated load is utilized to determine the output power command of the wind farm. To regulate the output power command of the wind farm according to wind speed changing, short-term ahead wind speed is predicted by using least-squares method. The predicted wind speed adjusts the output power command of the wind farm as a multiplying factor with fuzzy reasoning. By means of the proposed method, the windfarm can operate according to the wind and load conditions. In the windfarm system, each output power of the WTGs is controlled by regulating each pitch angle. For increasing acquisition power of the wind farm, a dispatch control method also is proposed. In the pitch angle control system of each WTG, generalized predictive control (GPC) is applied to enhance the control performance. Effectiveness of the proposed method is verified by the numerical simulations.

12/00870 Analysis of geo-temperature recovery under intermittent operation of ground-source heat pump

Shang, Y. *et al. Energy and Buildings*, 2011, 43, (4), 935–943.

In this paper, a three-dimensional model is presented to study the geo-temperature variation with the porous theory. The simulation is validated in comparison with experiment that carried out on the mode of heating. The model was used to predict the geo-temperature distribution in operation and recovery period of ground-source heat pump system. Moreover, the influencing factors including thermal conductivity, porosity, backfill material, air temperature, solar radiation energy and velocity of wind on the soil recovery process were calculated. The results show that the soil temperature recovers more quickly when heat conductivity increases and soil porosity decreases. Under the heating mode, the soil temperature recovers more quickly when the solar radiation and air temperature increase and the wind reduces. Furthermore, the results indicate that the soil properties have great effect on the soil recovery, however the environment factors have little effect.

12/00871 Application of metal foams in air-cooled condensers for geothermal power plants: an optimization study

Odabaee, M. and Hooman, K. *International Communications in Heat and Mass Transfer*, 2011, 38, (7), 838–843.

Optimized design of metal foam heat exchangers, as replacements for finned-tubes in air-cooled condensers of a geothermal power plant, is presented here. Two different optimization techniques, based on first and second law (of thermodynamics) are reported. While the former aims at the highest heat transfer rate with as low pressure drop as possible, the latter minimizes the generated entropy in the thermodynamic system. Interestingly, the two methods lead to the same optimal design. The new design has been compared to the conventional air-cooled condenser designed and optimized by using the commercially available software ASPEN. It is shown that while the heat transfer rate increases significantly (by an order of magnitude) compared to the finned-tube for the same main flow obstruction height, the pressure drop increase is within an acceptable range. Further comparisons between the two systems are carried out, making use of a performance factor developed specifically for metal foam heat exchangers.

12/00872 Evaluating the influence of thermal dispersion on temperature plumes from geothermal systems using analytical solutions

Molina-Giraldo, N. *et al. International Journal of Thermal Sciences*, 2011, 50, (7), 1223–1231.

An analytical study is carried out to examine the effect of thermal dispersion on the simulation of temperature plumes in aquifers that evolve from vertical ground source heat pump (GSHP) systems. Analytical solutions for the simulation of heat transport in aquifers often ignore thermal dispersion. In this study an existing two-dimensional analytical approach for transient conditions is used. Moreover, an equation to calculate the length of the temperature plume for steady state conditions is developed. To study the interplay between thermal dispersion and hydraulic conductivity, Darcy velocities are varied from 10^{-8} to 10^{-5} m/s and thermal dispersivities are varied based on two assumptions: (1) thermal dispersion is assumed to be only dependent on the Darcy velocity and (2) thermal dispersion is assumed to be scale-dependent. The results are discussed with respect to their implications for typical legal regulations and operation of such GSHP systems. In general, the effect of thermal dispersion on the temperature plume around the borehole heat exchanger (BHE) is minor when thermal dispersion is assumed to be depending solely on the magnitude of groundwater flow (e.g. in a homogeneous aquifer). On the other hand, based on a field scale of 10 m and assuming thermal dispersion to be scale-dependent, thermal dispersion can be neglected only for conditions typical for fine sands, clays, and silts with $q < 10^{-8}$ m/s. For aquifers where medium sands and gravels (with Darcy velocities $q > 10^{-8}$ m/s) dominate, thermal dispersion has a larger effect on the temperature plume distribution around the borehole heat exchanger.

12/00873 Experimental study of vertical ground-source heat pump performance evaluation for cold climate in Turkey

Ozyurt, O. and Ekinci, A. *Applied Energy*, 2011, 88, (4), 1257–1265.

Heat pump systems are recognized to be outstanding heating, cooling and water heating systems. They provide high levels of comfort as well as offering significant reductions in electrical energy use. In addition, they have very low levels of maintenance requirements and are environmentally attractive. The purpose of this study is to evaluate the experimental performance and energy analysis of vertical ground-source heat pump (GSHP) for winter climatic condition of Erzurum, Turkey. For this aim, an experimental analysis was performed on GSHP system made up in the energy laboratory in the campus of Ataturk University. The experimental apparatus consisted of a ground heat exchanger, the depth of which was 53 m, a liquid-to-liquid vapour compression heat pump, water circulating pumps and other measurement and control equipment. Tests were performed under laboratory conditions for space heating, in which experimental results were obtained during January–May within the heating season of 2007. The experimentally obtained results were used to calculate the heat pump coefficient of performance (COP) and the system performance (COPs). The COP and COPs were found to be in the range of 2.43–3.55 and 2.07–3.04, respectively. This study also shows that the system proposed could be used for residential heating in the province of Erzurum which is one of the coldest climate region of Turkey.

12/00874 Fluid origin, gas fluxes and plumbing system in the sediment-hosted Salton sea geothermal system (California, USA)

Mazzini, A. *et al. Journal of Volcanology and Geothermal Research*, 2011, 205, (3–4), 67–83.

The Salton sea geothermal system (California, USA) is an easily accessible setting for investigating the interactions of biotic and abiogenic geochemical processes in sediment-hosted hydrothermal systems. The authors present new temperature data and the molecular and isotopic composition of fluids seeping at the Davis-Schrimpf seep field during 2003–2008. Additionally, they show the first flux data for CO_2 and CH_4 released throughout the field from focused vents and diffuse soil degassing. The emitted gases are dominated by CO_2 ($\sim$98%) and CH_4 ($\sim$1.5%). By combining $\delta^{13}C_{CO2}$ (as low as -5.4‰) and $\delta^{13}C_{CH4}$ (-32‰ to -17.6‰) with $^3He/^4He$ (R/Ra > 6) and δD_{CH4} values (-216‰ to -150‰), it is suggested, in contrast to previous studies, that CO_2 may have a significant sub-continental mantle source, with minimal crustal contamination, and CH_4 seems to be a mixture of high temperature pyrolitic (thermogenic) and abiogenic gas. Water seeps show that δD and $\delta^{18}O$ increase proportionally with salinity (Total Dissolved Solids in g/L) ranging from 1–3 g/L (gryphons) to 145 g/L (hypersaline pools). In agreement with elemental analyses, the isotopic composition of the waters indicate a meteoric origin, modified by surface evaporation, with little or no evidence of deep fossil or magmatic components. Very high Cl/Br (>3000) measured at many

seeping waters suggests that increased salinities result from dissolution of halite crusts near the seep sites. Gas flux measurements from 91 vents (pools and gryphons) give a conservative estimate of ~2,100 kg of CO_2 and 11.5 kg of CH_4 emitted per day. In addition soil degassing measured at 81 stations (20×20 m grid over 51,000 m^2) revealed that 7,310 kg/d CO_2 and 33 kg/d CH_4 are pervasively released to the atmosphere. These results emphasize that diffuse gas emission from soil can be dominant (~75%) even in hydrothermal systems with large and vigorous gas venting. Sediment-hosted hydrothermal systems may represent an intermediate class of geologic methane sources for the atmosphere, with emission factors lower than those of sedimentary seepage in petroleum basins but higher than those of traditional geothermal-volcanic systems; on a global scale they may significantly contribute to the atmospheric methane budget.

12/00875 Fluids and parameters optimization for a novel cogeneration system driven by low-temperature geothermal sources

Guo, T. *et al. Energy*, 2011, 36, (5), 2639–2649.

A novel cogeneration system was proposed and techno-economically investigated, consisting of a low-temperature geothermally powered organic Rankine cycle (ORC) subsystem, an intermediate heat exchanger subsystem and a heat pump subsystem. The main purpose is to identify suitable working fluids (among 27 fluids with boiling point temperature ranging from −47.69 to 47.59 °C) and optimized cycle parameters for the ORC-based power generation subsystem. The screening criteria include net power output per unit mass flow rate of hot source (P_{net}), the ratio of total heat transfer area to net power output (A/W_{net}), and electricity production cost (epc). Results show that there exists optimum evaporating temperatures maximizing the P_{net} value and minimizing the A/P_{net} and epc values. The optimum temperatures vary with different screening criteria and fluids. Optimized fluids based on each screening criteria are not the same. E170, R600 and R141b show the lowest A/W_{net} and epc values with averagely 3.78% lower P_{net} value than R236ea which presents the largest P_{net} value.

12/00876 Geochemistry and groundwater contamination in the La Selva geothermal system (Girona, Northeast Spain)

Navarro, A. *et al. Geothermics*, 2011, 40, (4), 275–285.

Hot spring waters of the La Selva geothermal system show high concentrations of Cl, F, Ca, Na, K, Li, Si, As, Ba, and Rb, whereas cold waters show low salinity, high concentrations of NO_3, and significant As content when mixed with geothermal waters. Modelling of the geothermal fluids indicates that the fluid is supersaturated with aragonite and calcite, which matches the travertine precipitation close to the present discharge areas. Moreover, the barite and fluorite are also are near equilibrium levels, indicating possible control of Ba and F solubility by these mineral phases, which also precipitate in some discharge areas. Likewise, the fluid is supersaturated with respect to quartz, indicating the possibility of siliceous precipitation near the discharge areas of the present geothermal fluids. Taking into account the Na–K, Na–K–Ca, and SiO_2-temperature geothermometers, the temperature of the reservoir may be estimated to be about 135 °C. The chemistry of the geothermal fluids has changed from a recent high-enthalpy system, which precipitated siliceous deposits, to the present low-enthalpy system, which precipitates carbonated deposits (travertine). Multivariate analysis of the groundwater shows high correlations between K, Ca, As, Br, Ag, and Ba, suggesting that As is introduced to the environment via geothermal fluids. Moreover, As concentrations in hot groundwater are associated with high concentrations of Li and Si, as has been observed in other geothermal fields. Metal concentrations in the hydrothermal deposits show high values of Ag, As, Ba, Pb, Sb, and Zn, mainly in the siliceous deposits of the town of Caldes de Malavella, where the geothermal system deposited materials with high As concentrations (123–441 ppm). The similarities between the geochemical characteristics of the hydrothermal deposits and the groundwater suggest that the metals in these deposits and fluids have the same origin.

12/00877 Potential of autonomous ground-coupled heat pump system installations in Greece

Michopoulos, A. *et al. Applied Energy*, 2011, 88, (6), 2122–2129.

The HVAC systems utilizing renewable energy sources are one of the main contributors towards the fossil fuel dependency reduction. Among these, the ground source heat pump systems, especially those based on vertical ground heat exchanger, are very attractive, due to their high efficiency. The size of the systems depends on the building (geometry, construction materials, orientation etc. but also usage and internal gains), on the ground thermophysical characteristics, on the climatology of the area and on the ground heat exchanger design and construction. As a result, the ground heat exchanger length required for heating may result significantly different from the one required for cooling. In this work, the ground heat exchanger lengths required for heating and cooling are calculated for two model-buildings, a residential and an office one, located at 40 different Greek cities, covering a wide range of country's climate conditions. Assuming that a ratio of these lengths in the 0.8–1.2 range is required for efficient long-term operation of the autonomous GSHP system with minimum installation cost, the results suggest that autonomous systems may be used in areas with the heating degree-days in the 800–950 K-days range. In hotter climates with less than 800 heating degree-days, the GSHP system should be supplemented by a conventional cooling system, while in colder climates with more than 950 heating degree-days a conventional heating system supplement is required.

12/00878 Power generation from medium temperature geothermal resources: ANN-based optimization of Kalina cycle system-34

Arslan, O. *Energy*, 2011, 36, (5), 2528–2534.

Recent technical developments have made it possible to generate electricity from geothermal resources of low and medium enthalpy. One of these technologies is the Kalina cycle system. In this study, electricity generation from Simav geothermal field was investigated using the Kalina cycle system-34 (KCS-34). However, the design of these technologies requires more proficiency and longer times within complex calculations. An artificial neural network (ANN) is a new tool used to make a decision for the optimum working conditions of the processes within the expertise. In this study, the back-propagation learning algorithm with three different variants, namely Levenberg–Marguardt (LM), Pola–Ribiere conjugate gradient (CGP), and scaled conjugate gradient (SCG), were used in the network so that the best approach could be found. The most suitable algorithm found was LM with seven neurons in a single hidden layer. The obtained weights were used in optimization process by coupling the life-cycle-cost concepts.

12/00879 Techno-economic and spatial analysis of vertical ground source heat pump systems in Germany

Blum, P. *et al. Energy*, 2011, 36, (5), 3002–3011.

The objective of the current study was to assess the technical and economic factors that influence the design and performance of vertical GSHP (ground source heat pump) systems and to evaluate the spatial correlation that these factors have with geographic components such as geology and climatic conditions. The data from more than 1100 individual GSHP systems were analysed. The average capital cost of one GSHP system is about €23,500 ± €6800; the large standard deviation is primarily caused by local market dynamics. In comparison to other countries such as USA, Austria, Norway, UK and Sweden, the highest capital costs for vertical GSHP systems are in Germany and Switzerland, which is almost certainly partly due to economies of scale. Although geological, hydrogeological and thermal conditions in the studied state considerably vary spatially and the evaluated specific heat extraction rates are heterogeneously distributed, no correlation between the subsurface characteristics and the design of GSHP systems could be identified. This outcome suggests that as yet subsurface characteristics are not adequately considered during the planning and design of small-scale GSHP systems, which causes an undersizing or oversizing and therefore a long-term impact on the maintenance costs and payback time of such systems.

12/00880 The temperature penalty approach to the design of borehole heat exchangers for heat pump applications

Fossa, M. *Energy and Buildings*, 2011, 43, (6), 1473–1479.

Borehole heat exchangers (BHEs) are the most frequently adopted solution for ground coupled heat pump applications. In most installations, BHEs also represent the most important cost item, and a careful design analysis is needed to either assure long time performance or reduce the payback period, both parameters related to overall BHE length. The most efficient way, from a computational point of view, to predict the temperature evolution in time and space of a ground volume in contact with a system of BHE, is the recursive calculation of a basic thermal response factor, evaluated at different time steps and for given different heat pulses representing the building energy demand. Among the literature models, the Ashrae standard is the most simple method based on the above approach and it does not require, in principle, a dedicated computer code to solve the BHE sizing problem. In this paper a review of the existing response factor models for BHE analysis is performed and a new description of the Ashrae method is provided. In particular the real meaning of the temperature penalty parameter, fundamental in the Ashrae standard calculation, is clearly explained and a direct method for calculating the long-term effective ground resistance is given. The method is also able to take into account the geometrical disposition of multiple BHE at given overall length.

12/00881 Tracing thermal aquifers of El Chichón volcano–hydrothermal system (México) with $^{87}Sr/^{86}Sr$, Ca/Sr and REE

Peiffer, L. *et al. Journal of Volcanology and Geothermal Research*, 2011, 205, (3–4), 55–66.

The volcano–hydrothermal system of El Chichón volcano, Chiapas, Mexico, is characterized by numerous thermal manifestations including an acid lake, steam vents and boiling springs in the crater and acid and neutral hot springs and steaming ground on the flanks. Previous research on major element chemistry reveals that thermal waters of El Chichón can be divided in two groups: (1) neutral waters discharging in the crater and southern slopes of the volcano with chloride content ranging from 1500 to 2200 mg/l and (2) acid-to-neutral waters with Cl up to 12,000 mg/l discharging at the western slopes. This work supports the concept that each group of waters is derived from a separate aquifer (Aq. 1 and Aq. 2). Sr isotopes, Ca/Sr ratios and REE abundances along with the major and trace element water chemistry are applied in order to discriminate and characterize these two aquifers. Waters derived from Aq. 1 are characterized by $^{87}Sr/^{86}Sr$ ratios ranging from 0.70407 to 0.70419, while Sr concentrations range from 0.1 to 4 mg/l and Ca/Sr weight ratios from 90 to 180, close to average values for the erupted rocks. Waters derived from Aq. 2 have $^{87}Sr/^{86}Sr$ between 0.70531 and 0.70542, high Sr concentrations up to 80 mg/l, and Ca/Sr ratio of 17–28. Aquifer 1 is most probably shallow, composed of volcanic rocks and situated beneath the crater, within the volcano edifice. Aquifer 2 may be situated at greater depth in sedimentary rocks and by some way connected to the regional oil-gas field brines. The relative water output (l/s) from both aquifers can be estimated as Aq. 1/Aq. 2–30. Both aquifers are not distinguishable by their REE patterns. The total concentration of REE, however, strongly depends on the acidity. All neutral waters including high-salinity waters from Aq. 2 have very low total REE concentrations (<0.6 μg/l) and are characterized by a depletion in LREE relative to El Chichón volcanic rock, while acid waters from the crater lake (Aq. 1) and acid AS springs (Aq. 2) have parallel profile with total REE concentration from 9 to 98 μg/l. The highest REE concentration (207 μg/l) is observed in slightly acid shallow cold Ca-SO_4 ground waters draining fresh and old pyroclastic deposits rich in magmatic anhydrite. It is suggested that the main mechanism controlling the concentration of REE in waters of El Chichón is the acidity. As low pH results from the shallow oxidation of H_2S contained in hydrothermal vapours, REE distribution in thermal waters reflects the dissolution of volcanic rocks close to the surface or lake sediments as is the case for the crater lake.

12/00882 Transient 3D analysis of borehole heat exchanger modeling

Bauer, D. *et al*. *Geothermics*, 2011, 40, (4), 250–260.

This paper presents the development and application of a three-dimensional (3D) numerical simulation model for U-tube borehole heat exchangers (BHEs). The proposed model includes the thermal capacities of the borehole components, namely, the fluid inside the tubes, as well as the grouting material, making it possible to consider the transient effects of heat and mass transports inside the borehole. In this approach, the use of simplified thermal resistance and capacity models (TRCMs) provides accurate results while substantially reducing the number of nodes and the computation time compared with fully discretized computations such as finite element (FE) models. The model is compared with a fully discretized FE model which serves as a reference. Furthermore, the model is used to evaluate thermal response test (TRT) data by the parameter estimation technique. Comparison of the model results with the results of an analytical model based on the line-source theory further establishes the advantage of the developed 3D transient model, as the test duration can be shortened and results are more accurate.

Solar energy

12/00883 A comparative study of solar irradiation models on various inclined surfaces for India

Pandey, C. K. and Katiyar, A. K. *Applied Energy*, 2011, 88, (4), 1455–1459.

This paper presents a statistical approach for the estimation of the diffuse/global irradiation on various inclined surfaces from the measured data of horizontal surface. In fact diffuse solar radiation on an inclined plane consists of two components: sky diffuse radiation and reflected radiation from the ground. For analysing estimation of the daily tilted sky diffuse component from the daily horizontal diffuse irradiance, the authors have considered six models Badescu, Circumsolar, Skartveit and Olseth, Hay, Klucher and Liu and Jordan (isotropic). All these models except Badescu adopted the same methodology for estimating the ground-reflected radiation component, therefore, only sky diffuse component was analysed at Lucknow (latitude 26.75°, longitude 80.50°), India location. Statistical analysis showed that the Skartveit and Olseth model gives good prediction for the low inclination angle however; Klucher model gave better performance for highly inclined south-facing surfaces. The root mean square errors (% RMSE) value varies from 3.45% to 24.15% except for Badescu and Circumsolar model which predict worse results. In general, Klucher's model provides close agreement with the measurements.

12/00884 A simple and efficient algorithm to estimate daily global solar radiation from geostationary satellite data

Lu, N. *et al*. *Energy*, 2011, 36, (5), 3179–3188.

Surface global solar radiation (GSR) is the primary renewable energy in nature. Geostationary satellite data are used to map GSR in many inversion algorithms in which ground GSR measurements merely serve to validate the satellite retrievals. In this study, a simple algorithm with artificial neural network (ANN) modelling is proposed to explore the non-linear physical relationship between ground daily GSR measurements and multi-functional transport satellite (MTSAT) all-channel observations in an effort to fully exploit information contained in both data sets. Singular value decomposition is implemented to extract the principal signals from satellite data and a novel method is applied to enhance ANN performance at high altitude. A three-layer feed-forward ANN model is trained with a year's daily GSR measurements at 10 ground sites. This trained ANN is then used to map continuous daily GSR for 2 years, and its performance is validated at all 83 ground sites in China. The evaluation result demonstrates that this algorithm can quickly and efficiently build the ANN model that estimates daily GSR from geostationary satellite data with good accuracy in both space and time.

12/00885 An investigation on partial shading of PV modules with different connection configurations of PV cells

Wang, Y.-J. and Hsu, P.-C. *Energy*, 2011, 36, (5), 3069–3078.

Partial shading is a commonly encountered issue in a PV (photovoltaic) system. In this paper, five different connection configurations of PV cells are studied to compare their performance under the condition of partial shading. They are SS (simple series), SP (series-parallel), TCT (total-cross-tied), BL (bridge-linked) and HC (honey comb) configurations. The electric network of each connection configuration is analysed, taking into account the non-linear nature of PV cells, by writing the Kirchhoff's voltage and current equations. The analysis is followed by solving the simultaneous non-linear equations using the Newton–Raphson algorithm, which allows the I–V (current–voltage) characteristic of the module with a specific configuration in response to different types and levels of partial shading to be evaluated. Comparison of the maximum power and fill factors of the five connection configurations is then carried out. Also studied is the reverse voltage across each PV cell. It is found that in most cases, the TCT configuration has a superior performance over the other four configurations in most comparison indices.

12/00886 Analytic science for geospatial and temporal variability in renewable energy: a case study in estimating photovoltaic output in Arizona

Lee, S.-J. *et al*. *Solar Energy*, 2011, 85, (9), 1945–1956.

To assess the electric power grid environment under the high penetration of photovoltaic (PV) generation, it is important to construct an accurate representation of PV power output for any location in the south-western USA at resolutions down to 10-min time steps. Existing analyses, however, typically depend on sparsely spaced measurements and often include modelled data as a basis for extrapolation. Consequentially, analysts have been confronted with inaccurate analytic outcomes due to both the quality of the modelled data and the approximations introduced when combining data with differing space/time attributes and resolutions. This study proposes an accurate methodology for 10-min PV estimation based on the self-consistent combination of data with disparate spatial and temporal characteristics. The Type I estimation uses the nearby locations of temporally detailed PV measurements, whereas the Type II estimation goes beyond the spatial range of the measured PV incorporating alternative data set(s) for areas with no PV measurements; those alternative data sets consist of: (1) modelled PV output and secondary cloud cover information around space/time estimation points, and (2) their associated uncertainty. The Type I estimation identifies a spatial range from existing PV sites (30–40 km), which is used to estimate accurately 10-min PV output performance. Beyond that spatial range, the data-quality-control estimation (Type II) demonstrates increasing improvement over the Type I estimation that does not assimilate the uncertainty of data sources. The methodology developed herein can assist the evaluation of the impact of PV generation on the electric power grid, quantify the value of measured data, and optimize the placement of new measurement sites.

12/00887 Design and performance of energy-efficient solar residential house in Andorra

Llovera, J. *et al*. *Applied Energy*, 2011, 88, (4), 1343–1353.

This paper describes the design and building technology details of a three-storey single-family house located in the Pyrenees, in Andorra. The house is owned by the first author, and has been occupied since 2004. A combination of active and passive solar energy systems and night-time electricity are used to supply the heating and cooling demands. The main goal of this paper is to provide detailed design information and an evaluation of performance. Data provided includes site information and climate, basic design options and decisions, energy saving strategies and energy end use data. The house has been in use since 2003. This allows adequate performance data to be presented and evaluated. Some general results and initial design problems are discussed.

12/00888 Dynamic performances of solar heat storage system with packed bed using myristic acid as phase change material

Wu, S. and Fang, G. *Energy and Buildings*, 2011, 43, (5), 1091–1096.

This paper is aimed at analysing the thermal characteristics of packed bed containing spherical capsules, used in a latent heat thermal storage system with a solar heating collector. Myristic acid is selected as phase change material (PCM), and water is used as heat transfer fluid (HTF). The mathematical model based on the energy balance of HTF and PCM is developed to calculate the temperatures of PCM and HTF, solid fraction and heat release rate during the solidifying process. The latent efficiency, which is defined as the ratio between the instantaneous released latent heat and the maximum released heat, is introduced to indicate the thermal performances of the system. The inlet temperature of HTF (50 °C), flow rate of HTF (10 kg/min) and initial temperature of HTF (66 °C) were chosen for studying thermal performances in solar heat storage system. The influences of inlet temperature of HTF, flow rate of HTF and initial temperatures of HTF and PCM on the latent efficiency and heat release rate are also analysed and discussed.

12/00889 Early degradation of silicon PV modules and guaranty conditions

Munoz, M. A. *et al. Solar Energy*, 2011, 85, (9), 2264–2274.

The fast growth of PV installed capacity in Spain has led to an increase in the demand for analysis of installed PV modules. One of the topics that manufacturers, promoters, and owners of the plants are more interested in is the possible degradation of PV modules. This paper presents some findings of PV plant evaluations carried out during last years. This evaluation usually consists of visual inspections, I–V curve field measurements (the whole plant or selected areas), thermal evaluations by IR imaging and, in some cases, measurements of the I–V characteristics and thermal behaviours of selected modules in the plant, chosen by the laboratory. Electroluminescence technique is also used as a method for detecting defects in PV modules. It must be noted that new defects that arise when the module is in operation may appear in modules initially defect-free (called hidden manufacturing defects). Some of these hidden defects that only appear in normal operation are rarely detected in reliability tests (IEC61215 or IEC61646) due to the different operational conditions of the module in the standard tests and in the field (serial-parallel connection of many PV modules, power inverter influence, overvoltage on wires, etc.).

12/00890 Exergoeconomic analysis and optimization of an Integrated solar combined cycle system (ISCCS) using genetic algorithm

Baghernejad, A. and Yaghoubi, M. *Energy Conversion and Management*, 2011, 52, (5), 2193–2203.

In this study, thermoeconomic concept is applied using genetic algorithm for optimization of an integrated solar combined cycle system (ISCCS) that produces 400 MW of electricity. Attempt is made to minimize objective function including investment cost of equipment and cost of exergy destruction. Optimization process carried out by using exergoeconomic principles and genetic algorithm. The developed code first validated with a thermal system and good comparison is observed. Then the analysis is made for the ISCCS, and it shows that objective function for the optimum operation reduced by about 11%. Also cost of electricity produced by steam turbine and gas turbine in the optimum design of the ISCCS are about 7.1% and 1.17% lower with respect to the base case. These objectives are achieved with 13.3% increase in capital investment. Finally, sensitivity analysis is carried out to study the effect of changes in the unit cost of electricity for the system important parameters such as interest rate, plant lifetime, fuel cost, solar operation period and system construction period.

12/00891 Experimental diagnosis of the influence of operational variables on the performance of a solar absorption cooling system

Venegas, M. *et al. Applied Energy*, 2011, 88, (4), 1447–1454.

This paper presents the analysis of the performance of a solar cooling facility along one summer season using a commercial single-effect water–lithium bromide absorption chiller aiming at domestic applications. The facility works only with solar energy using flat plate collectors and it is located at Universidad Carlos III de Madrid, Spain. The statistical analysis performed with the gathered data shows the influence of five daily operational variables on the system performance. These variables are solar energy received along the day (H) and the average values, along the operating period of the solar cooling facility (from sunrise to the end of the cold-water production), of the ambient temperature ($\bar{T}$), the wind velocity magnitude (V), the wind direction (θ) and the relative humidity (RH). First order correlation functions are given. The analysis of the data allows concluding that the most influential variables on the daily cooling energy produced and the daily averaged solar COP are H, V and θ. The period length of cold-water production is determined mainly by H and ($\bar{T}$).

12/00892 Holding a candle to innovation in concentrating solar power technologies: a study drawing on patent data

Braun, F. G. *et al. Energy Policy*, 2011, 39, (5), 2441–2456.

Improved understanding of the innovative pathways of renewable energy technologies is vital if we are to make the transition to a low carbon economy. This study presents new evidence on innovation and industry dynamics in concentrating solar power (CSP) technologies. Though CSP is undergoing a renaissance, existing innovation studies have explored innovative activity in solar technologies in general, ignoring the major differences between solar photovoltaic and CSP technologies. This study, based on patent data, examines the level and dynamics of innovative activity in CSP between 1978 and 2004. This unique contribution, based on engineering expertise and detailed datawork, is a classification system mapping CSP technologies to the International Patent Classification (IPC) system. The innovation performance of CSP is found to be surprisingly weak compared to the patent boom in other green technologies. Performance was strong around 1980 before falling dramatically, and has only recently begun to show signs of recovery. Innovation and R&D are concentrated in high-tech countries; the US, Germany and Japan, which do not necessarily have high domestic CSP potential. Large CSP potential is, therefore, not a sufficient condition for innovation. Innovators must possess economic and scientific capabilities.

12/00893 MCFC integrated system in a biodiesel production process

Urbani, F. *et al. Journal of Power Sources*, 2011, 196, (5), 2691–2698.

The continuous increasing in biodiesel production by transesterification process is leading to an excess of glycerol production as a byproduct. The utilization of this huge amount of glycerol appears as a not easy solvable problem and thus several authors have proposed alternative ways. The integration of the main production process with a glycerol feed molten carbonate fuel cells bottoming cycle, to satisfy plant energy requirements, seems to be one of the most promising one. The proposed paper reports the main results obtained by authors in the framework of an investigation on a possible use of glycerol as energy sources for a real pilot plant for biodiesel production. An overall evaluation of worldwide biodiesel production plants was made and especially about the production capacity in European Union in the last decade. To make a more detailed study, authors were taken into account a real production plant. After a preliminary step, purported to plant mass and energy flows determination, authors considered the integration of a bottoming cycle based on: (i) steam reforming of glycerol for syn-gas production; (ii) molten carbonate fuel cells (MCFC) system supplied by syn-gas for heat and electricity production. A mathematical model, based on experimental data, has been developed to calculate mass and energy balances for the proposed plant lay-out as well as plant energy efficiency enhancement has been determined. Results have evidenced the feasibility of this process and demonstrated that plant integrated with bottoming cycle can reach a very high level of energy self-production.

12/00894 Minimum long-term cost solution for remote telecommunication stations on the basis of photovoltaic-based hybrid power systems

Kaldellis, J. K. *et al. Energy Policy*, 2011, 39, (5), 2512–2527.

In the case of the telecommunication (T/C) services' expansion to rural and remote areas, the market generally responds with the minimum investments required. Considering the existing situation, cost-effective operation of the T/C infrastructure installed in these regions (i.e. remote T/C stations) becomes critical. However, since in most cases grid-connection is not feasible, the up-to-now electrification solution for remote T/C stations is based on the operation of costly, oil consuming and heavy polluting diesel engines. Instead, the use of photovoltaic (PV)-based hybrid power stations is currently examined, using as a case study a representative remote T/C station of the Greek territory. In this context, the present study is concentrated on the detailed cost-benefit analysis of the proposed solution. More precisely, the main part of the analysis is devoted to develop a complete electricity production cost model, accordingly applied for numerous oil consumption and service period scenarios. Note that in all cases

examined, zero load rejections is a prerequisite while minimum long-term cost solutions designated are favourably compared with the diesel-only solution. Finally, a sensitivity analysis, demonstrating the impact of the main economic parameters on the energy production cost of optimum sized PV-diesel hybrid power stations, is also provided.

12/00895 Modeling and experimental validation of a humidification–dehumidification desalination unit solar part

Zhani, K. *et al. Energy*, 2011, 36, (5), 3159–3169.

This paper presents the modelling and the experimental validation of air and water solar collectors used in humidification–dehumidification (HDH) solar desalination unit. The solar desalination process is currently operating under the climatological conditions of Sfax (34° N, 10° E), Tunisia. To simulate numerically the air and water solar collectors, the authors have developed dynamic mathematical models of the solar collectors. The resulting distributed parametric systems of equations are transformed into a system of ordinary differential equations (ODEs) using the orthogonal collocation method (OCM). A comparison between numerical and experimental data was conducted. It was found that the two-temperature mathematical model describes more precisely the real behaviour of the water solar collector than the one-temperature mathematical model. It was also shown that the developed mathematical models are able to predict accurately the trends of the thermal characteristic of the water and air solar collectors. As a result, the proposed models can be used to size and test the behaviour of such a type of water and air solar collectors.

12/00896 Modeling and simulation of solar collector/regenerator for liquid desiccant cooling systems

Peng, D. and Zhang, X. *Energy*, 2011, 36, (5), 2543–2550.

Solar liquid collector/regenerator combines solar photothermic transformation and liquid regeneration together for solar energy-driven liquid desiccant cooling systems. A group of dimensionless heat and mass transfer equations describing the heat and mass transfer process in the solar C/R (collector/regenerator) were obtained by introducing total temperature difference (ΔT_0) and dimensionless heat loss coefficient ($\bar{h}_z$. The increment of solution concentration ΔC was increased 2.9–3.5%/°C and 5.3%/°C for increasing unit inlet temperature of air stream and solution respectively and increased about 6.2%/(g/kg) and 0.9%/(g/kg) for decreasing unit inlet humidity ratio of air and solution concentration. Besides, the increasing number of heat transfer units (NTU), air-to-salt mass flow rate ratio (ASMR) and total temperature difference (ΔT_0) can increase the performance of solution regeneration significantly. Compared to parallel flow regeneration, the performance of counterflow regeneration was increased about 10%.

12/00897 Optimization of tilt angle for solar panel: case study for Madinah, Saudi Arabia

Benghanem, M. *Applied Energy*, 2011, 88, (4), 1427–1433.

This article analyses the optimal choice of the tilt angle for the solar panel in order to collect the maximum solar irradiation. In this paper, the collector surface is assumed to be facing toward equator. The study is based upon the measured values of daily global and diffuse solar radiation on a horizontal surface. It is shown that the optimal angle of tilt (β_{opt}) for each month, allows us to collected the maximum solar energy for Madinah site. Annual optimum tilt angle is found to be approximately equal to latitude of the location. It is found that the loss in the amount of collected energy when using the yearly average fixed angle is around 8% compared with the monthly optimum tilt β_{opt}.

12/00898 Optimizing the design of a solar cooling system using central composite design techniques

Hang, Y. *et al. Energy and Buildings*, 2011, 43, (4), 988–994.

This paper presents the development of a method to optimize a solar-assisted cooling system with limited budget constraints. Regression analysis is used to identify the relationship between the solar fraction and the system factors according to the data provided by experiments. In order to obtain an accurate model to estimate the problem using small number of experimental trials, the method of central composite design (CCD) from design of experiment (DE) is used as a key technique. The experimental trials are conducted in the transient energy system simulation (TRNSYS) tool. Finally, the optimization problem is formulated and solved by including the model as the objective function, the physical constraints of the system factors, and the budget limit. A case study was conducted to apply this optimization method to the design of a solar-assisted double-effect absorption cooling system installed in a small-sized office building in West Lafayette, IN, USA. The results show the developed optimal model strongly agrees with the physical system model in TRNSYS. This optimization method can be generally applied to different types of solar cooling systems, and other renewable energy systems.

12/00899 Parameters extraction from commercial solar cells *I–V* characteristics and shunt analysis

Chen, Y. *et al. Applied Energy*, 2011, 88, (6), 2239–2244.

In this paper, an optimized method on the basis of polynomial fitting and Lambert W function is presented to extract parameters from the current–voltage (*I–V*) characteristics of commercial silicon solar cells. Since the experimental outcomes have significant impact on the precision of extracted parameters, polynomial fitting serves to overcome the obstacles of measurement noise in this method. The Lambert *W* function is employed to translate the transcendental equation into explicit analytical solution. Comparing with the as-reported parameters of a silicon cell and a plastic cell in the previous literature, the interesting outcomes demonstrate that the proposed approach is helpful for obtaining precise extracted data. This is further showed by the good agreements between the fitted *I–V* curve and the experimental results of a commercial monocrystalline silicon solar cell. Moreover, full extracted parameters of a badly shunted multicrystalline silicon solar cells before and after laser isolation process are conducted and investigated, the good fitting results finally show the validity of this attempt again.

12/00900 Parametric investigation of geometric form effects on solar potential of housing units

Hachem, C. *et al. Solar Energy*, 2011, 85, (9), 1864–1877.

The paper presents a study of the solar potential of different shapes of two-story single family housing units, located in mid-latitude climate. Seven plan geometries are studied: square, rectangle, trapezoid, L, U, H and T shapes. The study investigates the effect of these shapes on two major response variables – solar radiation incident on equatorial-facing facades and transmitted by the fenestration of such facades, and electricity production potential of building integrated photovoltaic (BIPV) covering roof surfaces with optimal solar exposure. The parameters, whose effects on the response variables are investigated, include, in addition to the basic shapes and roof design, variations to the geometry of L and U shapes and variations to the roof design. Shape variations include varying values of the relative dimensions of shading and shaded facades and variations to the angle enclosed by the wings of these shapes. Variations of roof design consist of modifications to the tilt and side angles of hip roofs. The results indicate that the number of shading facades in-self shading geometries and their relative dimensions are the major parameters affecting solar incident and transmitted radiation. Manipulation of the orientation of wings in L shape units can result in increased peak electricity generation potential, and in shifting the timing of the peak by up to 2 h either side of solar noon. The shift of peak load may be economically beneficial, facilitating more even distribution of electricity production over an assemblage of buildings. Judicious manipulation of unit shapes and window location can lead to optimization of solar radiation and its utilization for electricity generation and passive solar gain.

12/00901 Performance model for parabolic trough solar thermal power plants with thermal storage: comparison to operating plant data

García, I. L. *et al. Solar Energy*, 2011, 85, (10), 2443–2460.

This paper describes a simulation model that reproduces the performance of parabolic trough solar thermal power plants with a thermal storage system. The aim of this model is to facilitate the prediction of the electricity output of these plants during the various stages of their planning, design, construction and operation. Model results for a 50 MW_e power plant are presented and compared to real data from an equivalent power plant currently operated by the ACS industrial group in Spain.

12/00902 Photovoltaics on flat roofs: energy considerations

Bayod-Rújula, A. A. *et al. Energy*, 2011, 36, (4), 1996–2010.

Flat roofs present a large potential of suitable areas for installation of PV (photovoltaic) plants. Flat roof PV installations have the advantage of being able to be optimally positioned with support structures, and the inclination angle can be adjusted. Due to the important technological development existing in the PV sector, there are different PV technologies in the market, whose energy and economic features substantially differ. This paper describes some useful parameters to assess the technology and distribution of modules to be installed in flat roofs and terraces of buildings. The effect on the energy parameters of the modules tilt and disposition is analysed in a case study, considering different technologies.

12/00903 Theoretical and experimental investigation of the filled-type evacuated tube solar collector with U tube

Liang, R. *et al. Solar Energy*, 2011, 85, (9), 1735–1744.

The filled-type evacuated tube with U-tube, in which the filled layer is used to transfer energy absorbed by the working fluid flowing in the U-tube, is proposed to eliminate the influence of thermal resistance between the absorber tube and the copper fin of the conventional evacuated solar collector. In this paper, the thermal performance of the filled-type evacuated tube with U-tube was researched by means of theoretical analysis and experimental study. The temperature of the

working fluid in the flow direction was obtained, and the efficiency of the evacuated tube was also calculated, based on the energy balance equations for the working fluid in the U-tube. The effects of the heat loss coefficient and the thermal conductivity of the filled layer on the thermal performance of the evacuated tube were studied. In addition, the test setup of the thermal performance of the filled-type evacuated tube with U-tube was established. The evacuated tube considered in this study was a two-layered glass evacuated tube, and the absorber film was deposited in the outer surface of the absorber tube. The results show that the filled-type evacuated tube with U-tube has a favourable thermal performance. When the thermal conductivity of the heat transmission component is $\lambda_c = 100$, the efficiency of the filled-type evacuated tube with U-tube is 12% higher than that of the U-tube evacuated tube with a copper fin. The modelling predictions were validated using experimental data which show that there is a good concurrence between the measured and predicted results.

12/00904 Thermal behavior in solar air heater channel fitted with combined rib and delta-winglet

Promvonge, P. *et al. International Communications in Heat and Mass Transfer*, 2011, 38, (6), 749–756.

Effects of combined ribs and delta-winglet type vortex generators (DWs) on forced convection heat transfer and friction loss behaviours for turbulent airflow through a solar air heater channel are experimentally investigated in the present work. Measurements are carried out in the rectangular channel of aspect ratio, $AR = 10$ and height, $H = 30$ mm. The flow rate is presented in the form of Reynolds numbers based on the inlet hydraulic diameter of the channel ranging from 5000 to 22,000. The cross-section shape of the rib placed on the absorber plate to create a reverse-flow is an isosceles triangle with a single rib height, $e/H = 0.2$ and rib pitch, $Pl/H = 1.33$. Ten pairs of the DW with its height, $b/H = 0.4$; transverse pitch, $Pt/H = 1$ and three attack angles (α) of 60°, 45° and 30° are introduced and mounted on the lower plate entrance of the tested channel to generate longitudinal vortex flows. The experimental results show that the Nusselt number and friction factor values for combined rib and DW are found to be much higher than those for the rib/DW alone. The larger attack angle of the DW leads to higher heat transfer and friction loss than the lower one. In common with the rib, the DW pointing upstream (PU-DW) is found to give higher heat transfer rate and friction loss than the DW pointing downstream (PD-DW) at a similar operating condition. In comparison, the largest attack angle ($\alpha = 60°$) of the PU-DW yields the highest increase in both the Nusselt number and friction factor while the lowest attack angle of the PD-DW provides the best thermal performance.

12/00905 Thermal performance analysis and economic evaluation of roof-integrated solar concrete collector

Sarachitti, R. *et al. Energy and Buildings*, 2011, 43, (6), 1403–1408.

This paper examines the thermal performance of a roof-integrated solar concrete collector for reducing heat gain to a house and providing domestic hot water. The solar concrete collector is made of PVC pipes embedded in a deck slab or a concrete roof. No glazing on the top of the solar concrete collector or insulation at the back has been used as in conventional solar water heaters. To compare the energy saving, two test rooms of 2.3 m width, 2.5 m length and 2.5 m height were built. In the first room, the reinforced cement concrete (RCC) slab was used as deck slab whereas the second room was equipped with a cement concrete solar collector. The experimental results showed that the cement concrete solar collector is extremely interesting as it can produce up to 40 litres of hot water per day at water temperatures ranging from 40 to 50 °C. A mathematical model based on the conservation equations of energy is developed to predict the performance of the cement concrete solar collector. There is reasonable agreement from the comparison between measured data and predicted results. The economic analysis indicates that the payback period is rather fast.

12/00906 Thermal performance investigation of double pass-finned plate solar air heater

El-Sebaii, A. A. *et al. Applied Energy*, 2011, 88, (5), 1727–1739.

In this paper, the double pass-finned plate solar air heater was investigated theoretically and experimentally. An analytical model for the air heater was presented. Numerical calculations had been performed under Tanta (latitude, 30°47′N and longitude, 31°E) prevailing weather conditions. The theoretical predictions indicated that the agreement with the measured performance is fairly good. Comparisons between the measured outlet temperatures of flowing air, temperature of the absorber plate and output power of the double pass-finned and v-corrugated plate solar air heaters were also presented. The effect of mass flow rates of air on pressure drop, thermal and thermohydraulic efficiencies of the double pass-finned and v-corrugated plate solar air heaters were also investigated. The results showed that the double pass v-corrugated plate solar air heater is 9.3–11.9% more efficient compared to the double pass-finned plate solar air heater. It was also indicated that the peak values of the thermohydraulic efficiencies of the double pass-finned and v-corrugated plate solar air heaters were obtained when the mass flow rates of the flowing air equal 0.0125 and 0.0225 kg/s, respectively.

12/00907 Thermodynamic analysis of solar energy use for reforming fuels to hydrogen

Wagar, W. R. *et al. International Journal of Hydrogen Energy*, 2011, 36, (12), 7002–7011.

In this paper, a method is proposed for reforming fuels to hydrogen using solar energy at distributed locations (industrial sites, residential and commercial buildings fed with natural gas, remote settlements supplied by propane, etc.). In order to harness solar energy a solar concentrator is used to generate high temperature heat to reform fuels to hydrogen. A typical fuel such as natural gas, propane, methanol, or an atypical fuel such as ammonia or urea can be transported to distributed locations via gas networks or other means. The thermodynamic analysis of the process shows the general reformation reactions for NH_3, CH_4 and C_3H_8 as the input fuel by comparison through operational fuel cost and CO_2 mitigation indices. Through a cost analysis, cost reduction indices show fuel-usage cost reductions of 10.5%, 22.1% and 22.2%, respectively for the reformation of ammonia, methane and propane. CO_2 mitigation indices show fuel-usage CO_2 mitigations of 22.1% and 22.3% for methane and propane respectively, where ammonia reformation eliminates CO_2 emission at the fuel-usage stage. The option of reforming ammonia is examined in further detail as proposed cycles for solar energy capture are considered. A mismatch of specific heats from the solar dish is observed between incoming and outgoing streams, allowing a power production system to be included for a more complete energy capture. Further investigation revealed the most advantageous system with a direct expansion turbine being considered rather than an external power cycle such as Brayton or Rankine type cycles. Also, an energy efficiency of approximately 93% is achievable within the reformation cycle.

Wind energy

12/00908 A new probabilistic method to estimate the long-term wind speed characteristics at a potential wind energy conversion site

Carta, J. A. and Velázquez, S. *Energy*, 2011, 36, (5), 2671–2685.

This paper proposes the use of a new measure–correlate–predict (MCP) method to estimate the long-term wind speed characteristics at a potential wind energy conversion site. The proposed method uses the probability density function of the wind speed at a candidate site conditioned to the wind speed at a reference site. Contingency-type bivariate distributions with specified marginal distributions are used for this purpose. The proposed model was applied in this paper to wind speeds recorded at six weather stations located in the Canary Islands (Spain). The conclusion reached is that the method presented in this paper, in the majority of cases, provides better results than those obtained with other MCP methods used for purposes of comparison. The metrics employed in the analysis were the coefficient of determination (R^2) and the root relative squared error (RRSE). The characteristics that were analysed were the capacity of the model to estimate the long-term wind speed probability distribution function, the long-term wind power density probability distribution function and the long-term wind turbine power output probability distribution function at the candidate site.

12/00909 ARMA based approaches for forecasting the tuple of wind speed and direction

Erdem, E. and Shi, J. *Applied Energy*, 2011, 88, (4), 1405–1414.

Short-term forecasting of wind speed and direction is of great importance to wind turbine operation and efficient energy harvesting. In this study, the forecasting of wind speed and direction tuple is performed. Four approaches based on autoregressive moving average (ARMA) method are employed for this purpose. The first approach features the decomposition of the wind speed into lateral and longitudinal components. Each component is represented by an ARMA model, and the results are combined to obtain the wind direction and speed forecasts. The second approach employs two independent ARMA models – a traditional ARMA model for predicting wind speed and a linked ARMA model for wind direction. The third approach features vector autoregression (VAR) models to forecast the tuple of wind attributes. The fourth approach involves employing a restricted version of the VAR approach to predict the same. By employing these four approaches, the hourly mean wind attributes are forecasted 1-h ahead for two wind observation sites in North Dakota, USA. The results are compared using the mean absolute error (MAE) as a measure for forecasting quality. It is found

that the component model is better at predicting the wind direction than the traditional-linked ARMA model, whereas the opposite is observed for wind speed forecasting. Utilizing VAR approaches rather than the univariate counterparts brings modest improvement in wind direction prediction but not in wind speed prediction. Between restricted and unrestricted versions of VAR models, there is little difference in terms of forecasting performance.

12/00910 Critical evaluation of financial supporting schemes for wind-based projects: case study Greece

Kaldellis, J. K. *Energy Policy*, 2011, 39, (5), 2490–2500.

After a long stagnating period during the second half of the 1990s, the market of wind energy in Greece was described by remarkable but unstable growth rates that resulted in the operation of 1 GW of wind power by the end of 2009. Still though, penetration of wind energy is not the one anticipated. On the other hand, national targets regarding the renewable energy sources' (RES) contribution and existence of excellent wind potential areas across Greece challenge new wind energy investments. Acknowledging the unsteady development rates of wind power in Greece, efficiency of the State support mechanisms is currently investigated. Based on an analytical evaluation model, the investigation undertaken is extended to provide a detailed cost-benefit analysis of several wind energy case studies, including mainland and island applications as well as comparison with both conventional power stations and photovoltaic plants. For this purpose, the financial support provided by the State is directly compared with benefits accruing from the operation of wind parks, considering also the avoidance of social costs deriving from thermal power stations. Based on the results obtained, the beneficial characteristics of wind energy applications for the Greek society are clearly demonstrated, especially in the case of non-interconnected island grids.

12/00911 Demand side resource operation on the Irish power system with high wind power penetration

Keane, A. *et al. Energy Policy*, 2011, 39, (5), 2925–2934.

The utilization of demand-side resources is set to increase over the coming years with the advent of advanced metering infrastructure, home area networks and the promotion of increased energy efficiency. Demand-side resources are proposed as an energy resource that, through aggregation, can form part of the power system plant mix and contribute to the flexible operation of a power system. A model for demand-side resources is proposed here that captures its key characteristics for commitment and dispatch calculations. The model is tested on the all island Irish power system, and the operation of the model is simulated over a year in both a stochastic and deterministic mode, to illustrate the impact of wind and load uncertainty. The results illustrate that demand-side resources can contribute to the efficient, flexible operation of systems with high penetrations of wind by replacing some of the functions of conventional peaking plant. Demand-side resources are also shown to be capable of improving the reliability of the system, with reserve capability identified as a key requirement in this respect.

12/00912 Economics of compressed air energy storage to integrate wind power: a case study in ERCOT

Fertig, E. and Apt, J. *Energy Policy*, 2011, 39, (5), 2330–2342.

Compressed air energy storage (CAES) could be paired with a wind farm to provide firm, dispatchable baseload power, or serve as a peaking plant and capture upswings in electricity prices. The authors present a firm-level engineering-economic analysis of a wind/CAES system with a wind farm in central Texas, load in either Dallas or Houston, and a CAES plant whose location is profit-optimized. With 2008 hourly prices and load in Houston, the economically optimal CAES expander capacity is unrealistically large – 24 GW – and dispatches for only a few hours per week when prices are highest; a price cap and capacity payment likewise results in a large (17 GW) profit-maximizing CAES expander. Under all other scenarios considered the CAES plant is unprofitable. Using 2008 data, a baseload wind/CAES system is less profitable than a natural gas combined cycle (NGCC) plant at carbon prices less than \$56/tCO_2 (\$15/MMBTU gas) to \$230/tCO_2 (\$5/MMBTU gas). Entering regulation markets raises profit only slightly. Social benefits of CAES paired with wind include avoided construction of new generation capacity, improved air quality during peak times, and increased economic surplus, but may not outweigh the private cost of the CAES system nor justify a subsidy.

12/00913 Enhancement of micro-grid performance during islanding mode using storage batteries and new fuzzy logic pitch angle controller

Kamel, R. M. *et al. Energy Conversion and Management*, 2011, 52, (5), 2204–2216.

Power system deregulation, shortage of transmission capacities and needing to reduce greenhouse gas emissions have led to increase interesting in distributed generations (DGs) especially renewable sources. This study developed a complete model able to analysis and simulates in details the transient dynamic performance of the micro-grid during and subsequent islanding process. Wind speed fluctuations cause high fluctuations in output power of wind turbine which lead to fluctuations of frequency and voltages of the micro-grid during the islanding mode. In this paper a new fuzzy logic pitch angle controller is proposed to smooth the output power of wind turbine to reduce micro-grid frequency and voltage fluctuations during the islanding mode. The proposed fuzzy logic pitch controller is compared with the conventional PI pitch angle controller which usually used for wind turbine power control. Results proved the effectiveness of the proposed fuzzy controller in improvement of the micro-grid performance. Also, this paper proposed using storage batteries technique to reduce the frequency deviation and fluctuations originated from wind power solar power fluctuations. Results indicate that the storage batteries technique is superior to a fuzzy logic pitch controller in reducing frequency deviation, but with more expensive than the fuzzy controller. All models and controllers are built using the Matlab Simulink environment.

12/00914 Fine tuning support vector machines for short-term wind speed forecasting

Zhou, J. *et al. Energy Conversion and Management*, 2011, 52, (4), 1990–1998.

Accurate forecasting of wind speed is critical to the effective harvesting of wind energy and the integration of wind power into the existing electric power grid. Least-squares support vector machines (LS-SVM), a powerful technique that is widely applied in a variety of classification and function estimation problems, carries great potential for the application of short-term wind speed forecasting. In this case, tuning the model parameters for optimal forecasting accuracy is a fundamental issue. This paper, for the first time, presents a systematic study on fine tuning of LS-SVM model parameters for one-step ahead wind speed forecasting. Three SVM kernels, namely linear, Gaussian, and polynomial kernels, are implemented. The SVM parameters considered include the training sample size, SVM order, regularization parameter, and kernel parameters. The results show that (1) the performance of LS-SVM is closely related to the dynamic characteristics of wind speed; (2) all parameters investigated greatly affect the performance of LS-SVM models; (3) under the optimal combination of parameters after fine tuning, the three kernels give comparable forecasting accuracy; (4) the performance of linear kernel is worse than the other two kernels when the training sample size or SVM order is small. In addition, LS-SVMs are compared against the persistence approach, and it is found that they can outperform the persistence model in the majority of cases.

12/00915 On wind speed pattern and energy potential in Nigeria

Adaramola, M. S. and Oyewola, O. M. *Energy Policy*, 2011, 39, (5), 2501–2506.

The aim of this paper is to review wind speed distribution and wind energy availability in Nigeria and discuss the potential of using this resource for generation of wind power in the country. The power output from a wind turbine is strongly dependent on the wind speed and accurate information about the wind data in a targeted location is essential. The annual mean wind speeds in Nigeria range from about 2 to 9.5 m/s and the annual power density range between 3.40 and 520 kW/m^2 based on recent reported data. The trend shows that wind speeds are low in the south and gradually increases to relatively high speeds in the north. The areas that are suitable for exploitation of wind energy for electricity generation as well as for water pumping were identified. Also some of the challenges facing the development of wind energy and suggested solutions were presented.

12/00916 Power quality assessment of wind turbines and comparison with conventional legal regulations: a case study in Turkey

Tascikaraoglu, A. *et al. Applied Energy*, 2011, 88, (5), 1864–1872.

Renewable energy sources have been investigated for use instead of conventional fossil fuels in many areas. Among these renewable energy sources, wind energy has come into prominence owing to the fact that it is a clean, sustainable and cost-effective type of energy. However, the connection of large wind farms to the grid may cause problems in terms of power quality due to the variability of the energy extracted from the wind. The mentioned power quality problems are generally taken into consideration after the grid integration of wind farms. However, the precautions that can be taken by means of the assessments before the installation of the turbines represent an easier and more economic way. In this study, the possible effects of the grid connected wind turbines on the power quality characteristics have been defined and the MATLAB based models have been constructed so as to calculate these effects. Particularly, fast voltage variations that are difficult to model due to their relations with the human factor have been analysed in detail. It has been aimed that the models are suitable for use in practice while utilizing various standards such as IEC 61400–21 and

IEC 61000–4–15 in order to setup the models. The analyses of the implementations that represent constraints for exploiting the wind resources in Turkey have been realized in terms of production and consumption with a case study. The realized calculations present the applicability of the model to grid conditions with different characteristics. It is also presented that the wind energy penetration can be increased without deteriorating the power quality of the grid with the use of the proposed model.

12/00917 Robust control of an isolated hybrid wind–diesel power system using linear quadratic Gaussian approach
Kassem, A. M. and Yousef, A. M. *International Journal of Electrical Power & Energy Systems*, 2011, 33, (4), 1092–1100.
This paper presents the application of the linear quadratic Gaussian (LQG) controller for voltage and frequency regulation of an isolated hybrid wind–diesel scheme. The scheme essentially consists of a vertical axis wind turbine driving a self-excited induction generator connected via an asynchronous (AC–DC–AC) link to a synchronous generator driven by a diesel engine. The synchronous generator is equipped with a voltage regulator and a static exciter. The wind generator and the synchronous generator together cater for the local load and power requirement. However, the load bus voltage and frequency are governed by the synchronous generator. The control objective aims to regulate the load voltage and frequency. This is accomplished via controlling the field voltage and rotational speed of the synchronous generator. The complete non-linear dynamic model of the system has been described and linearized around an operating point. The standard Kalman filter technique has been employed to estimate the full states of the system. The computational burden has been minimized to a great extent by computing the optimal state feedback gains and the Kalman state space model off-line. The proposed controller has the advantages of robustness, fast response and good performance. The hybrid wind diesel energy scheme with the proposed controller has been tested through a step change in both wind speed and load impedance. Simulation results show that accurate tracking performance of the proposed hybrid wind diesel energy system has been achieved.

Others, including economics

12/00918 A comparison of the drivers influencing adoption of on-farm anaerobic digestion in Germany and Australia
Wilkinson, K. G. *Biomass and Bioenergy*, 2011, 35, (5), 1613–1622.
This review examines the drivers behind the adoption of on-farm anaerobic digestion in Germany where there were more than 4000 plants operating in 2009. In Australia, only one plant is operating, at a piggery in the State of Victoria. Germany's generous feed-in-tariffs for renewable energy are typically given the credit for promoting investment in on-farm anaerobic digestion. But the particular biophysical and socio-economic character of farming in the country provided the fertile ground for these financial incentives to take root. Energy security has also been a major driver for the promotion of renewable energy in Germany since it imports over 60% of its energy needs. In contrast, Australia is a net energy exporter, exporting about two-thirds of its domestic energy. Although it has considerable potential for application in Australia, anaerobic digestion is unlikely to be widely adopted unless new incentives emerge to strongly encourage investment. Stronger Australian regulation of manures and effluent may serve as an incentive to a limited extent in the future. Yet the experience in Germany suggests that regulation on its own was not sufficient to encourage large numbers of farmers to invest in anaerobic digestion. Even with generous incentives from the German government, increasing construction costs and the rising cost of energy crops can put the financial viability of anaerobic digestion plants at risk. Unless improvements in efficiency are found and implemented, these pressures could lead to unsustainable rises in the cost of the incentive schemes that underpin the development of renewable energy technologies.

12/00919 A critical review of the applicability of biodiesel and grass biomethane as biofuels to satisfy both biofuel targets and sustainability criteria
Thamsiriroj, T. and Murphy, J. D. *Applied Energy*, 2011, 88, (4), 1008–1019.
There are numerous ways to assess and compare biofuels. Gross energy per hectare reflects the quantity of product produced per unit of land. Net energy per hectare reflects the parasitic demand associated with the product per hectare. Gross and net energy per hectare are far superior for grass biomethane than rape seed biodiesel. For a biofuel made from residues the descriptor (MJ of biofuel produced per GJ of fossil fuel displaced) is more instructive; this reflects the relative efficiency of the biofuel. Of issue in the assessment is how to deal with co-products, by-products and residues. The allocation methodology allows for a variety of answers to be generated. Used cooking oil biodiesel has a good energy balance for any allocation approach; tallow biodiesel has a poor net energy unless credit is given for the co-production of meat and bone meal as a substitute fuel. To be deemed sustainable by the European Union's renewable energy directive a value of 60% greenhouse gas savings is required for facilities built post-2017. A further crucial consideration is: how much fuel can be produced? This study shows that indigenous biodiesel produced in Ireland and grass biomethane may be deemed sustainable but only grass biomethane may produce a significant quantity, potentially satisfying the 10% renewable energy in transport target for 2020 as opposed to only 1.23% in total from all indigenous biodiesel systems.

12/00920 A genetic algorithm solution to the optimal short-term hydrothermal scheduling
Kumar, V. S. and Mohan, M. R. *International Journal of Electrical Power & Energy Systems*, 2011, 33, (4), 827–835.
This paper presents an algorithm for solving the hydrothermal scheduling through the application of genetic algorithm (GA). The hydro subproblem is solved using GA and the thermal subproblem is solved using lambda iteration technique. Hydro and thermal subproblems are solved alternatively. GA based optimal power flow (OPF) including line losses and line flow constraints are applied for the best hydrothermal schedule obtained from GA. A nine-bus system with four thermal plants and three hydro plants and a 66-bus system with 12 thermal plants and 11 hydro plants are taken for investigation. This proposed GA reduces the complexity, computation time and also gives near global optimum solution.

12/00921 A mobile renewable house using PV/wind/fuel cell hybrid power system
Eroglu, M. *et al. International Journal of Hydrogen Energy*, 2011, 36, (13), 7985–7992.
A photovoltaic/wind/fuel cell hybrid power system for stand-alone applications is proposed and demonstrated with a mobile house. This concept shows that different renewable sources can be used simultaneously to power off-grid applications. The presented mobile house can produce sufficient power to cover the peak load. Photovoltaic and wind energy are used as primary sources and a fuel cell as backup power for the system. The power budgeting of the system is designed based on the local data of solar radiation and wind availability. Further research will focus on the development of the data acquisition system and the implementation of automatic controls for power management.

12/00922 Designing effective and efficient incentive policies for renewable energy in generation expansion planning
Zhou, Y. *et al. Applied Energy*, 2011, 88, (6), 2201–2209.
This study presents a bilevel optimization approach to designing effective and efficient incentive policies for stimulating investment in renewable energy. The effectiveness of an incentive policy is its capability to achieve a goal that would not be achievable without it. Renewable portfolio standards are used in this paper as the policy goal. The efficiency of an incentive policy is measured by the amount of policy intervention, such as taxes collected or subsidies paid, to achieve the policy goal. The authors obtain the most effective and efficient incentive policies in the context of generation expansion planning, in which a centralized planner makes investment decisions for the energy system to serve projected demand of electricity. A case study is conducted on integrated coal transportation and electricity transmission networks representing the contiguous USA. The numerical analysis from the case study provides insights on the comparison of various incentive policies. The sensitivity of the incentive policies with respect to coal production cost, wind energy investment cost, and transmission capacity is also studied.

12/00923 Determining the regional potential for a grass biomethane industry
Smyth, B. M. *et al. Applied Energy*, 2011, 88, (6), 2037–2049.
Grass biogas/biomethane has been put forward as a renewable energy solution and it has been shown to perform well in terms of energy balance, greenhouse gas emissions and policy constraints. Biofuel and energy crop solutions are country-specific and grass biomethane has strong potential in countries with temperate climates and a high proportion of grassland, such as Ireland. For a grass biomethane industry to develop in a country, suitable regions (i.e. those with the highest potential) must be identified. In this paper, factors specifically related to the assessment of the potential of a grass biogas/biomethane industry are identified and analysed. The potential for grass biogas and grass biomethane is determined on a county-by-county basis using multi-criteria decision analysis. Values are assigned to each county and ratings and weightings applied to determine the overall county potential. The potential for grass biomethane with co-digestion of

slaughter waste (belly grass) is also determined. The county with the highest potential (Limerick) is analysed in detail and is shown to have ready potential for production of gaseous biofuel to meet either 50% of the vehicle fleet or 130% of the domestic natural gas demand, through 25 facilities at a scale of about 30 kt year^{-1} of feedstock. The assessment factors developed in this paper can be used in other resource studies into grass biomethane or other energy crops.

12/00924 Double-sided wet fabric evaporator utilizing wind and solar energy efficiently – one-dimensional transient simulations

Nosoko, T. *et al. International Communications in Heat and Mass Transfer*, 2011, 38, (6), 723–729.

The performance of the double-sided fabric seawater evaporator, suggested in an earlier study, was simulated for a sunny day under subtropical and maritime climate conditions by one-dimensional transient modelling. The concentration of seawater increases exponentially with the downstream distance along the fabric while the temperature and the evaporation rate increase gradually. In a polyester fabric, seawater flows fast and the concentration of the effluent brine is kept constant in a small range by adjusting the rate of influent seawater according with the solar radiation. In a cotton fabric, seawater flows slow, causes a large time lag between the influent and effluent, and thus varies the effluent concentration greatly. The temperature and evaporation rate of the polyester are approximately the same as those of the cotton. The daily evaporation is 9.41 kg/day m^2– fabric under a solar radiation of 27.6 MJ/m^2. The lumped capacitance model was found to predict quite accurately the averages of the evaporation rate and temperature of fabric, but to fail in prediction of the temporal variations of the effluent concentration.

12/00925 Economic evaluation of renewable energy systems under varying scenarios and its implications to Korea's renewable energy plan

Koo, J. *et al. Applied Energy*, 2011, 88, (6), 2254–2260.

This paper studies economics of renewable energy systems with consideration of future prospects on costs and uncertain external conditions that may affect competitiveness in the power plant market. The concept of learning curve is adopted to compute estimates on the costs of installing and operating renewable energy systems in the future; fuel costs and carbon price are modelled as scenario-dependent variables to analyse their impact on total costs under different scenarios. The proposed approach allows evaluation and comparison of total costs necessary in implementing renewable energy plans under varying technological, and/or economical conditions that face uncertainty at present. Moreover, analysing the evaluation results further with techniques like sensitivity analysis can identify factors central to reducing the total costs. As an illustrative case-study, the Korean government's renewable energy plan has been evaluated accordingly, under three different scenarios defined by International Energy Agency (IEA). The evaluation results indicate minor changes in total costs of achieving the plan among three scenarios, mainly due to counterbalancing between the price of fossil fuels and carbon price. Further analyses revealed factors central to lowering the total costs necessary in implementing the plan – hybridization between renewable energy systems, reduction of biomass production costs via technological innovation, increasing learning rates by focusing on R&D and international co-operation.

12/00926 Estimating national costs, benefits, and potential for cellulosic ethanol production from forest thinnings

Kocoloski, M. *et al. Biomass and Bioenergy*, 2011, 35, (5), 2133–2142.

Since 2004, wildfires have been responsible for the destruction of 3.5 million hectares of forestland per year. Fuel reduction activities such as prescribed fires, cutting and burning *in situ*, and biomass removal (thinning) have been shown to reduce wildfire severity, but with mounting costs of fighting wildfires and a tightening budget, public agencies such as the USDA forest service may find it difficult to continue funding these preventative treatments. By using thinned biomass as a cellulosic ethanol feedstock, these agencies may be able to generate funds for these treatments. Here, the authors estimate costs of producing cellulosic ethanol from forest thinnings based on forest thinning supply curves. Nationally, 27–34 million Mg of biomass could be removed from overcrowded forests per year at collection costs of $55 to $110 per dry Mg. Given a mature cellulosic ethanol industry, ethanol produced from these thinnings could generate revenue at gasoline prices of $0.5 to $0.8 per litre. By using thinned biomass as an ethanol feedstock, it may be possible to generate significant funds for socially beneficial thinning treatments.

12/00927 Forecasting ocean wave energy: the ECMWF wave model and time series methods

Reikard, G. *et al. Ocean Engineering*, 2011, 38, (10), 1089–1099.

This paper analyses the forecasting properties of a well-known physics-based model, the European Centre for Medium-Range Weather Forecasts (ECMWF) wave model, and two statistical techniques, time-varying parameter regressions and neural networks. Thirteen data sets at locations in the Atlantic and Pacific Oceans and the Gulf of Mexico are tested. The quantities to be predicted are the significant wave height, the wave period, and the wave energy flux. In the initial tests, the ECMWF model and the statistical models are compared directly. The statistical models do better at short horizons, producing more accurate forecasts in the 1–5 h range. The ECMWF model is superior at longer horizons. The convergence point, at which the two methods achieve comparable degrees of accuracy, is in the area of 6 h. By implication, the physics-based model captures the underlying signals at lower frequencies, while the statistical models capture relationships over shorter intervals. Further tests are run in which the forecasts from the ECMWF model are used as inputs in regressions and neural networks. The combined models yield more accurate forecasts than either one individually.

12/00928 Hydrogen production by steam reforming of liquefied natural gas (LNG) over mesoporous Ni–La–Al_2O_3 aerogel catalysts: effect of La content

Bang, Y. *et al. International Journal of Hydrogen Energy*, 2011, 36, (14), 8307–8315.

Mesoporous Ni–La–Al_2O_3 aerogel catalysts (denoted as (40-*x*)Ni*x*La) with different lanthanum content (*x*) were prepared by a single-step sol-gel method and a subsequent CO_2 supercritical drying method. The effect of lanthanum content on the physicochemical properties and catalytic performance of mesoporous (40-*x*)Ni*x*La catalysts in the steam reforming of liquefied natural gas (LNG) was investigated. Physicochemical properties of (40-*x*)Ni*x*La catalysts were strongly influenced by lanthanum content. Dispersion and reducibility of nickel aluminate phase in the (40-*x*)Ni*x*La catalysts increased with increasing lanthanum content. Small amount of lanthanum addition was effective for dispersion of metallic nickel in the (40-*x*)Ni*x*La catalysts, but large amount of lanthanum addition was not favourable for nickel dispersion due to the blocking of active sites. In the steam reforming of LNG, both LNG conversion and hydrogen yield showed volcano-shaped curves with respect to lanthanum content. Average nickel diameter of (40-*x*)Ni*x*La catalysts was well correlated with LNG conversion and hydrogen yield over the catalysts. Among the catalysts tested, 36Ni4La (36 wt% Ni and 4 wt% La) catalyst with the smallest average nickel diameter exhibited the best catalytic performance and the strongest resistance toward carbon deposition in the steam reforming of LNG.

12/00929 Is there an optimum level for renewable energy?

Moriarty, P. and Honnery, D. *Energy Policy*, 2011, 39, (5), 2748–2753.

Because continued heavy use of fossil fuel will lead to both global climate change and resource depletion of easily accessible fuels, many researchers advocate a rapid transition to renewable energy (RE) sources. This paper examines whether RE can provide anywhere near the levels of primary energy forecast by various official organizations in a business-as-usual world. The authors find that the energy costs of energy will rise in a non-linear manner as total annual primary RE output increases. In addition, increasing levels of RE will lead to increasing levels of ecosystem maintenance energy costs per unit of primary energy output. The result is that there is an optimum level of primary energy output, in the sense that the sustainable level of energy available to the economy is maximized at that level. They further argue that this optimum occurs at levels well below the energy consumption forecasts for a few decades hence.

12/00930 Net energy balance of small-scale on-farm biodiesel production from canola and soybean

Fore, S. R. *et al. Biomass and Bioenergy*, 2011, 35, (5), 2234–2244.

One necessary criterion for a biofuel to be a sustainable alternative to the petroleum fuels it displaces is a positive net energy balance. This study estimated the net energy ratio (NER), net energy balance (NEB), and net energy yield (NEY) of small-scale on-farm production of canola [*Brassica napus* (L.)] and soybean [*Glycine max* (L.)] biodiesel in the upper Midwest. Direct and embodied energy inputs based on well-defined system boundaries and contemporary data were used to estimate the energy requirement of crop production, oil extraction, and biofuel processing. The NER of canola biodiesel was 1.78 compared with 2.05 for soybean biodiesel. Canola biodiesel had a NEB of 0.66 MJ MJ^{-1} of biofuel compared with 0.81 MJ MJ^{-1} for soybean biodiesel. The NEY of soybean biodiesel was 10,951 MJ ha^{-1}, less than canola biodiesel which had a NEY of 11,353 MJ ha^{-1}. Use of soybean as a biodiesel feedstock was more energetically efficient than canola primarily due to reduced nitrogen fertilizer requirement. In terms of energetic productivity, canola was a more productive biodiesel feedstock than soybean due to its higher oil content. A best-case scenario based on optimal feedstock yields, reduced fertilizer input, and

advanced biofuel processing equipment suggested that potential gains in energetic efficiency was greater for canola than soybean. According to these results, small-scale on-farm biodiesel production using canola and soybean can be an energetically efficient way to produce energy for on-farm use.

12/00931 Optimal time-invariant operation of a power and water cogeneration solar-thermal plant

Ghobeity, A. *et al. Solar Energy*, 2011, 85, (9), 2295–2320.

Conceptual design, system-level models, and optimization of operation are presented for a cogeneration solar-thermal plant. The solar-thermal energy collected and concentrated in a salt pond is used in a regenerative Rankine steam cycle with an extraction turbine to produce electricity and process steam. The desalination system is based on reverse osmosis (RO) and multi-effect distillation (MED). An equation-oriented modelling environment is used for the development of time-dependent system-level models required for optimization of the plant. A meteorological radiation model is used to estimate the hourly distribution of beam radiation as a function of time (day and hour), location, and local weather (mainly visibility and humidity). A recently developed model is used to estimate the field efficiency, including projection losses and shading/blocking for a given heliostat layout. Time-invariant optimal operating conditions are presented for a summer day, considering Cyprus as a case study. Seawater desalination processes, RO and MED, are modelled by adapting and extending models from the literature. A control-volume model is developed for the steam cycle based on the first and second law, with given isentropic efficiencies, turbine leaks, and a detailed model for thermodynamic properties of steam/water. This model is validated and allows for optimization over a wide range of operating conditions, e.g. various extraction pressures. The optimization problem is formulated as a non-linear program (NLP) with dynamics embedded and a heuristic global optimization approach is used. The sequential method of optimization is used, decoupling the simulation from the optimization. The results show that for the plant size considered (4 MW_e equivalent nominal capacity) and the MED design chosen based on the literature and industry practice, RO is preferred over MED from an energy point of view. In addition, under the current feed-in tariff (FiT) and water prices in Cyprus, extracting steam for MED is not recommended. In contrast, if current market prices for electricity and water in Cyprus are used, i.e. FiT is neglected, with a typical steam cycle design, extracting steam for MED at low pressures yields maximum income. A new process configuration is presented based on the findings from the case studies, resulting in significantly higher income and exergetic efficiencies.

12/00932 Optimizing biofuel production: an economic analysis for selected biofuel feedstock production in Hawaii

Tran, N. *et al. Biomass and Bioenergy*, 2011, 35, (5), 1756–1764.

Hawaii's agricultural sector has an immense supply of natural resources that can be further developed and utilized to produce biofuel. Transformation of the renewable and abundant biomass resources into a cost competitive, high performance biofuel could reduce Hawaii's dependence on fossil fuel importation and enhance energy security. The objectives of the study are to evaluate the economic feasibility of selected bioenergy crops for Hawaii and compare their cost competitiveness. The selected feedstock consists of both ethanol and biodiesel producing crops. Ethanol feedstock includes sugar feedstock (sugarcane) and lignocellulosic feedstock (banagrass, Eucalyptus, and Leucaena). Biodiesel feedstock consists of Jatropha and oil palm. The economic analysis is divided into two parts. First, a financial analysis was used to select feasible feedstock for biofuel production. For each feedstock, net return, feedstock cost per Btu, feedstock cost per gallon of ethanol/biodiesel, breakeven price of feedstock and breakeven price of ethanol/biodiesel were calculated. Leucaena shows the lowest feedstock cost per Btu while banagrass has the highest positive net returns in terms of both feedstock price and energy price. The second approach assumes an objective of maximizing net returns. Given this assumption, biofuel producers will produce only banagrass. As an example, the production of bioenergy on the island of Hawaii is illustrated where 74,793 acres of non-prime land having a 'warm and moist' soil temperature and moisture regime are available. Using average yields (static optimization), banagrass production on this acreage can yield 8.24 trillion Btus of energy (ethanol). This satisfies the State's 10% self-sufficiency energy goal of 3.9 trillion Btus by 2010. Incorporating risk through variability in crop yields and biofuel prices separately shows banagrass as having the highest probability for receiving a positive net return. Banagrass is the leading candidate crop for biofuel production in Hawaii and the State of Hawaii ethanol goal can be achieved by allocating non-prime lands for banagrass production without compromising prime lands currently allocated for agricultural food production in Hawaii. Physical, environmental and socio-economic impacts should be accounted for in evaluating future biofuel projects.

12/00933 Renewable and hydrogen energy integrated house

Bocci, E. *et al. International Journal of Hydrogen Energy*, 2011, 36, (13), 7963–7968.

The residential sector accounts for about a third of the total world energy consumption. Energy efficiency, renewable energy sources and hydrogen can play an important role in reducing the consumptions and the emissions and improving the energy security if integrated (efficiency, RES, hydrogen) systems are developed and experimented. The paper analyses a real residential 100 m^2 house, where energy efficiency measures and RES technologies have been applied, sizing a hydrogen system (electrolyser, metal hydrides and fuel cell) for power backup, taking into consideration its dynamic behaviour, experimentally determined. The technologies used are already available in the market and, except hydrogen technologies, sufficiently mature. Through energy efficiency technologies (insulation, absorbers, etc.), the maximum electrical and thermal power needed decreases from 4.4 to 1.7 kW*e* (annual consumption from 5000 to 1200 kWh) and from 5.2 to 1.6 kW*t* (annual consumption from 14,600 to 4500 kWh) respectively. With these reduced values it has been possible to supply the consumptions entirely by small photovoltaic and solar thermal plants (less than 10 m^2 each). The hydrogen backup even if remains the most expensive (versus traditional batteries and gasoline generator), satisfying all the electric needs for one day, increases the security and allows net metering. Moreover the low-pressure hydrogen storage system through metal hydrides guarantees system safety too. Finally the system modularity can also satisfy higher energy production.

12/00934 Renewable resource and capital with a joy-of-giving resource bequest motive

Bréchet, T. and Lambrecht, S. *Resource and Energy Economics*, 2011, 33, (4), 981–994.

This paper considers whether a privately owned natural renewable resource can be conserved and managed efficiently when households have a joy-of-giving resource bequest motive. They authors model an overlapping generations economy in which firms have access to a CES production technology combining the natural resource, physical capital and labour. The results shed light on the interplay between the resource bequest motive and the substitutability/complementarity relationship between capital and the natural resource in the determination of the equilibrium propensity to use the resource. The mere existence of the bequest motive does not guarantee that the resource will be conserved in the long run. When the resource is highly substitutable with capital, the equilibrium actually never exhausts the resource stock whatever the intensity of the bequest motive. When the resource is a poor substitute for capital, the equilibrium preserves the resource only if the taste for bequeathing is strong enough. Be the economy in over-accumulation or in under-accumulation of the natural resource, it always increases aggregate consumption to run the stock of capital at a level lower than the efficiency level.

12/00935 Techno-economic valuation and optimization of integrated photovoltaic/wind energy conversion system

Kaabeche, A. *et al. Solar Energy*, 2011, 85, (10), 2407–2420.

Decentralized electricity generation by renewable energy sources offer greater security of supply for consumers while respecting the environment. But the random nature of these sources requires us to develop sizing rules and use these systems to exploit them. This paper proposes an integrated PV/wind hybrid system optimization model, which utilizes the iterative optimization technique following the deficiency of power supply probability (DPSP), the relative excess power generated (REPG), the total net present cost (TNPC), the total annualized cost (TAC) and break-even distance analysis (BEDA) for power reliability and system costs. The flow chart of the hybrid optimal sizing model is also illustrated. With this merged model, the optimal size of PV/wind hybrid energy conversion system using battery bank can be performed technically and economically according to the system reliability requirements. Additionally, a sensitivity analysis was carried out in order to appreciate the most important parameters influencing the economic performances of the hybrid system. A case study is conducted to analyse one hybrid project, which is designed to supply small residential household situated in the area of the Centre for Renewable Energy Development (CDER) located in Bouzaréah, Algeria (36°48′N, 3°1′E, 345 m).

12/00936 TESPI: thermal electric solar panel integration

Rosa-Clot, M. *et al. Solar Energy*, 2011, 85, (10), 2433–2442.

A photovoltaic panel with a heat extraction system is studied. The solution suggested consists of superimposing a water layer on the PV panel: the water layer absorbs the infrared radiation leaving the visible part almost unaffected. This allows a good PV efficiency and heat production. This particular setup is called thermal electric solar panel integration (TESPI) and it is discussed in detail both for the electric

and the thermal part. The engineering problems are briefly analysed and results of an experimental campaign are given. A definition of the global thermal-electric efficiency is given.

12/00937 The CO removal performances of Cr-free Fe/Ni catalysts for high temperature WGSR under LNG reformate condition without additional steam
Lee, J. Y. *et al. International Journal of Hydrogen Energy*, 2011, 36, (14), 8173–8180.
The goal of this study was to investigate Cr-free, Fe/Ni, metal oxide catalysts for the high temperature shift (HTS) reaction of a fuel processor using liquefied natural gas (LNG). As hexavalent chromium (Cr^{6+}) in commercial HTS catalyst is a hazardous material, the authors selected Ni as a substitute for chromium in the Fe-based HTS catalyst and investigated the HTS activities of these Cr-free, metal oxide catalysts under the LNG reformate condition. Cr-free, Fe/Ni-based catalysts containing Ni instead of Cr were prepared by coprecipitation and their performance was evaluated under a gas mixture condition (56.7% H_2, 10% CO, 26.7% H_2O, and 6.7% CO_2) that simulated the gas composition from a steam methane reformer (SMR, at H_2O/CH_4 ratio = 3 with 100% CH_4 conversion). Under this condition, the Fe/Ni catalysts showed higher CO removal activities than Fe-only and Cr-containing catalysts, but the methanation was promoted when the Ni content in the catalyst exceeded 50 wt%. Brunner–Emmett–Teller (BET), X-ray diffraction (XRD), inductively coupled plasma (ICP) and X-ray photoelectron spectroscopy (XPS) analyses were performed to explain the HTS activity of the Fe/Ni catalysts based on the catalyst structure.

12/00938 The portfolio of renewable energy sources for achieving the three E policy goals
Shen, Y.-C. *et al. Energy*, 2011, 36, (5), 2589–2598.
Renewable energy is considered by many policy-makers to contribute to achieving at least three major policy goals: the energy goal, the environmental goal, and the economic goal (3E goals). As an innovation-oriented island country with scarce natural resources, Taiwan announced the sustainable energy policy principles in 2008 that stated that Taiwan's renewable energy policy should accomplish the 3E goals. Several studies point out that specific renewable energy policy goals lead to specific renewable energy sources and technologies because each type of renewable energy has different features. In order to achieve the renewable energy policy goals, this research aims to examine how different policy goals lead to corresponding renewable energy sources. The relative importance of each goal is evaluated by using analytic hierarchy process (AHP). The weight of each policy goal is adjusted separately to construct policy scenarios by the sensitivity analysis. According to the results, non-pumped storage hydropower, wind energy, and solar energy are three sources that could meet the three policy goals at the same time.

12/00939 The status and prospects of renewable energy for combating global warming
Arent, D. J. *et al. Energy Economics*, 2011, 33, (4), 584–593.
Reducing anthropogenic greenhouse gas (GHG) emissions in material quantities, globally, is a critical element in limiting the impacts of global warming. GHG emissions associated with energy extraction and use are a major component of any strategy addressing climate change mitigation. Non-emitting options for electrical power and liquid transportation fuels are increasingly considered key components of an energy system with lower overall environmental impacts. Renewable energy technologies (RETs) as well as biofuels technologies have been accelerating rapidly during the past decades, both in technology performance and cost-competitiveness – and they are increasingly gaining market share. These technology options offer many positive attributes, but also have unique cost/benefit trade-offs, such as land-use competition for bioresources and variability for wind and solar electric generation technologies. This paper presents a brief summary of status, recent progress, some technological highlights for RETs and biofuels, and an analysis of critical issues that must be addressed for RETs to meet a greater share of the global energy requirements and lower GHG emissions.

12/00940 U.S. state policies for renewable energy: context and effectiveness
Delmas, M. A. and Montes-Sancho, M. J. *Energy Policy*, 2011, 39, (5), 2273–2288.
Over the past decade, state policies on renewable energy have been on the rise in the USA, providing states with various options for encouraging the generation of renewable electricity. Two promising policies, the renewable portfolio standard (RPS) and the mandatory green power option (MGPO), have been implemented in many states but the evidence about their effectiveness is mixed. In this paper, the authors argue that recognizing the natural, social, and policy context under which MGPO and RPS are adopted is necessary in order to measure their true effectiveness. This is because the context rather than the policy might lead to positive outcomes and there is the possibility for sample bias. When controlling for the context in which the policies are implemented, RPS is found to have a negative impact on investments in renewable capacity. However, investor-owned utilities seem to respond more positively to RPS mandates than publicly owned utilities. By contrast, MGPO appears to have a significant effect on installed renewable capacity for all utilities regardless of the context in which it is implemented.

12/00941 What lessons have been learned in reforming the renewables obligation? An analysis of internal and external failures in UK renewable energy policy
Wood, G. and Dow, S. *Energy Policy*, 2011, 39, (5), 2228–2244.
Despite operating a delivery programme for RES-E since 1990, UK targets and policy goals have not been achieved. In response, the government reformed the renewables obligation (RO). This article re-examines UK renewable energy policy by analysing the internal and external failures of the various mechanisms to determine if government has learnt from previous experience in reforming the RO. Government did not learn from their own actions during the NFFO/RO transition, evidenced by high-levels of similarity in internal/external failures. The reformed-RO is expected to significantly increase deployment, has provided a 'renewables package' by comprehensively addressing both internal/external failures but major internal failures (price/financial risk) still remain, resulting in contiguous failures over two decades and two mechanism changes (NFFO, RO, RO/reformed-RO). Success will again be heavily dependent on a select few technologies and new/untested measures to combat external failures. Mechanism-extension to 2037 is probably the single most important factor underlying potential deployment increases. However, introducing a FIT-like system via the sheer number of 'bolt-on' reforms to counter policy failures indicates loss of direction and clarity. Overall, although government appears to have learnt some of its lessons from the past two-decades, significant doubt remains whether renewable energy policy objectives will be met via the latest mechanism change.

14 FUEL SCIENCE AND TECHNOLOGY

Fundamental science, analysis, instrumentation

12/00942 A hybrid multi-objective cultural algorithm for short-term environmental/economic hydrothermal scheduling
Lu, Y. *et al. Energy Conversion and Management*, 2011, 52, (5), 2121–2134.
The short-term environmental/economic hydrothermal scheduling (SEEHS) with the consideration of multiple objectives is a complicated non-linear constrained optimization problem with non-smooth and non-convex characteristics. In this paper, a multi-objective optimization model of SEEHS is proposed to consider the minimal of fuel cost and emission effects synthetically, and the transmission loss, the water transport delays between connected reservoirs as well as the valve-point effects of thermal plants are taken into consideration to formulate the problem precisely. Meanwhile, a hybrid multi-objective cultural algorithm (HMOCA) is presented to deal with SEEHS problem by optimizing both two objectives simultaneously. The proposed method integrated differential evolution (DE) algorithm into the framework of cultural algorithm model to implement the evolution of population space, and two knowledge structures in belief space are redefined according to the characteristics of DE and SEEHS problem to avoid premature convergence effectively. Moreover, in order to deal with the complicated constraints effectively, new heuristic constraint handling methods without any penalty factor settings are proposed in this paper. The feasibility and effectiveness of the proposed HMOCA method are demonstrated by two case studies of a hydrothermal power system. The simulation results reveal that, compared with other methods established recently, HMOCA can get better quality solutions by reducing fuel cost and emission effects simultaneously.

12/00943 A novel current mode controller for a static compensator utilizing Goertzel algorithm to mitigate voltage sags

Najafi, E. and Yatim, A. H. M. *Energy Conversion and Management*, 2011, 52, (4), 1999–2008.

Static compensator (STATCOM) has been widely proposed for power quality and network stability improvement. It is easily connected in parallel to the electric network and has many advantages for electrical grids. It can improve network stability; power factor, power transfer rating and can avoid some disturbances such as sags and swells. Most of STATCOM controllers are based on voltage controllers that are based on balanced d–q transform. However, they are not thorough solutions for network disturbances since in most cases single-phase disturbances occur in electrical networks that cannot be avoided by the conventional controllers. Voltage mode controllers are also not capable of responding fast enough to the changes expected of a network system. This paper proposes a new current mode controller to overcome the mentioned problem. The approach uses a fixed frequency current controller to maintain voltage levels in voltage sags (dips). This approach is also simple and can be easily implemented by digitally. It has superior performance over conventional methods in terms of harmonic reduction in STATCOM output current. Another important factor for STATCOM effectiveness in sag mitigation is its sag detection method. This paper also introduces a new sag detection method based on Goertzel algorithm which is both effective and simple for practical applications. The simulation results presented illustrate the superiority of the proposed controller and sag detection algorithm to be utilized in the STATCOM.

12/00944 A numerical investigation of creep-fatigue life prediction utilizing hysteresis energy as a damage parameter

Oldham, J. and Abou-Hanna, J. *International Journal of Pressure Vessels and Piping*, 2011, 88, (4), 149–157.

This paper explores the hypothesis that there exists an intrinsic material property, hysteresis damage energy at failure, which could be used as a creep-fatigue life prediction parameter. The connection between hysteresis energy and fatigue damage was introduced in the 1920s by Inglis, but the use of hysteresis energy as a measure of damage was first presented by Morrow and Halford. Hysteresis energy shows promise in bridging the gaps associated with life prediction when the combination of both creep and fatigue scenarios are present. Numerical simulations which replicate experimental test configurations with 9Cr–1Mo steel were performed from which the hysteresis energy failure density (HEFD) could be calculated for each experiment. Taking the average of the HEFD values calculated for all of the experimental data as the parameter for failure ($E_{Intrinsic}$), creep-fatigue life predictions were made using a simplistic hysteresis energy based method as well as the time fraction/cycle fraction method endorsed by ASME code and compared to experimental results. A good correlation with experimental results was obtained for life predictions using hysteresis energy density as a damage parameter. An investigation of the interaction between creep damage and fatigue damage based on the hysteresis energy method was also performed and compared with the damage interaction diagram utilized by the ASME and RCC-MR design codes. The hysteresis energy based method proved easy to implement and gave improved accuracy over the time fraction/cycle fraction method for low cycle creep-fatigue loading.

12/00945 A time-convolution approach for modelling heat exchange between a wellbore and surrounding formation

Zhang, Y. *et al. Geothermics*, 2011, 40, (4), 261–266.

In oil, gas, and geothermal energy production, as well as geological CO_2 storage, the target formation is typically deeper than 1000 metres. As a result, associated wellbores have a large heat exchange area with the surrounding formation. Large gradients and temporal variations in temperature induced by the injection and production of fluids require accurate and efficient ways to calculate the heat exchange between fluids in the wellbore and the formation. One way to calculate this heat exchange is to fully discretize and numerically model the formation that surrounds the wellbore. However, because only the energy equation needs to be solved (i.e. there is no fluid exchange between the cased wellbore and the formation), this approach is computationally inefficient. This study proposes a time-convolution method, where only the wellbore is fully discretized, and heat exchange between fluids in the wellbore and the formation is calculated using semi-analytical solutions of radial conductive heat flow. The time-dependent temperature evolution in the wellbore is calculated numerically using a wellbore simulator for non-isothermal, multiphase fluid mixtures. At each time step, radial heat transfer with the formation is calculated by superposition of analytical solutions of heat flow that are dependent on the temperature differences between subsequent time steps. This coupling scheme is implemented in the TOUGH2 suite of reservoir simulators. To verify the proposed semi-analytical method and demonstrate its applicability, examples are given and compared to full numerical solutions.

12/00946 Application of GA optimization for automatic generation control design in an interconnected power system

Golpîra, H. *et al. Energy Conversion and Management*, 2011, 52, (5), 2247–2255.

This paper addresses a realistic model for automatic generation control (AGC) design in an interconnected power system. The proposed scheme considers generation rate constraint (GRC), dead band, and time delay imposed to the power system by governor-turbine, filters, thermodynamic process, and communication channels. Simplicity of structure and acceptable response of the well-known integral controller make it attractive for the power system AGC design problem. The genetic algorithm (GA) is used to compute the decentralized control parameters to achieve an optimum operating point. A three-control area power system is considered as a test system, and the closed-loop performance is examined in the presence of various constraints scenarios. It is shown that neglecting above physical constraints simultaneously or in part, leads to impractical and invalid results and may affect the system security, reliability and integrity. Taking to account the advantages of GA besides considering a more complete dynamic model provides a flexible and more realistic AGC system in comparison of existing conventional schemes.

12/00947 CO_2 escapes in the Laacher See region, East Eifel, Germany: application of natural analogue onshore and offshore geochemical monitoring

Gal, F. *et al. International Journal of Greenhouse Gas Control*, 2011, 5, (4), 1099–1118.

Natural analogues studies have received growing interest during preceding years in a CCS perspective. There is a strong willing to deploy robust and reliable technologies to ensure the safety and integrity of CO_2 underground storages. Here the authors present a dataset acquired in the Eifel volcanic district, using geochemical monitoring methods focusing on both dissolved and gaseous species. Onshore and offshore monitoring (Lake Laacher See) were performed to depict spatial behaviour of CO_2 natural releases. Additional gaseous species, mainly helium and radon, were also monitored to better assess the shapes of gas vents, using methodologies that were learned from hydrological and tectonic applications. Lake water monitoring allowed the characterization of the water body itself, in terms of lateral heterogeneities, to evaluate the impact of CO_2 deep degassing near the bottom of the lake. The use of a dedicated sensor for monitoring *in situ* CO_2 partial pressure did not provide more valuable information that was learned from more classical physico-chemical parameters. From those investigations, the usefulness of geochemical monitoring is still demonstrated, but the use of complementary approaches and methods is still needed to get a powerful set of techniques able to warn in case of leakages occurring from depth.

12/00948 Decomposition analysis of energy consumption in Chinese transportation sector

Zhang, M. *et al. Applied Energy*, 2011, 88, (6), 2279–2285.

The purpose of this paper is to identify the relations between transportation energy consumption and its impacted factors. The authors first analyse the current status of transportation energy consumption in China. Then, the logarithmic mean divisia index (LMDI) technique is used to find the nature of the factors those influence the changes in transportation energy consumption. It was found that: (1) In 2006, the transportation energy consumption increased by 7.63 times against that in 1980. (2) Up to 2006, the oil consumed by transportation accounted for 49.6% of that in the whole country, which almost equalled to the net oil import. (3) In the light of the increasing energy consumption intensity, the energy-utilization effectiveness of transportation sector has been declining gradually. (4) The transportation activity effect is the most important contributor to increase energy consumption in the transportation sector and the energy intensity effect plays the dominant role in decreasing energy consumption.

12/00949 Effect of mounting geometry on convection occurring under a photovoltaic panel and the corresponding efficiency using CFD

Wilson, M. J. and Paul, M. C. *Solar Energy*, 2011, 85, (10), 2540–2550.

Computational fluid dynamics (CFD) is used to model experimental data corresponding to convection occurring under a photovoltaic (PV) panel. Further experimental data are used to validate the model where the satisfactory agreement is received. A standardized condition is set up to allow the effect of varying three geometric parameters to be examined. These are the air gap height (10–500 mm), air gap orientation angle (0–90° from the horizontal) and fluid velocity magnitude (0–3 m/s). The optimum mounting conditions for the PV

panel is obtained and maximized electrical efficiency found to favour angles greater than 50° and air gap heights that give an aspect ratio of 60. Mixed convection opposed to natural convection is found to be more effective, with greater efficiencies obtained for larger fluid velocities.

12/00950 Enabling machine understandable exchange of energy consumption information in intelligent domotic environments

Bonino, D. *et al. Energy and Buildings*, 2011, 43, (6), 1392–1402.

Energy conservation and its efficient usage have become key issues for many governments. In the last decade, the drive to make homes automated and to deliver a better assisted living picked pace and the research into home automation systems accelerated, usually based on a centralized residential gateway. However, most devised solutions fail to provide users with information about power consumption of different house appliances. The ability to collect power consumption information can result in a more energy efficient society. This paper investigates how residential gateways can provide energy consumption information, in a machine-understandable format, to support third-party applications and services. To do this a semantic energy information publishing framework is proposed. This publishes, for different appliances in the house, power consumption information and other properties, in a machine-understandable format. Appliance properties are released according to the existing semantic modelling supported by residential gateways, while instantaneous power consumption is modelled through a new modular energy profile ontology.

12/00951 Energy and exergy analysis of an indirect solar cabinet dryer based on mathematical modeling results

Sami, S. *et al. Energy*, 2011, 36, (5), 2847–2855.

In the present study, using a previously developed dynamic mathematical model for performance analysis of an indirect cabinet solar dryer, a microscopic energy and exergy analysis for an indirect solar cabinet dryer is carried out. To this end, appropriate energy and exergy models are developed and using the predicted values for temperature and enthalpy of gas stream and the temperature, enthalpy and moisture content of the drying solid, the energy and exergy efficiencies are estimated. The validity of the model for predicting variations in gas and solid characteristics along the time and the length of the solar collector and/or dryer length was examined against some existing experimental data. The results show that in spite of high energy efficiency, the indirect solar cabinet dryer has relatively low exergy efficiency. Results show that the maximum exergy losses are in midday. Also the minimums of total exergy efficiency are 32.3% and 47.2% on the first and second days, respectively. Furthermore, the effect of some operating parameters, including length of the collector, its surface, and air flow rate was investigated on the exergy destruction and efficiency.

12/00952 Energy efficiency, rebound effects and the environmental Kuznets curve

Turner, K. and Hanley, N. *Energy Economics*, 2011, 33, (5), 709–720.

Technological change is one factor used to justify the existence of an environmental Kuznets curve (EKC), and technological improvements have been argued to be a key factor in mitigating the impacts of economic growth on environmental quality. This study used a computable general equilibrium (CGE) model of the Scottish economy to consider the factors influencing the impacts of one form of technological change–improvements in energy efficiency–on absolute levels of CO_2 emissions, on the carbon intensity of the economy (CO_2 emissions relative to real GDP), and the per capita EKC relationship. These factors include the elasticity of substitution between energy and non-energy inputs, responses in the labour market and the structure of the economy. The results demonstrate the key role played by the general equilibrium price elasticity of demand for energy, and the relative influence of different factors on this parameter.

12/00953 Energy efficiency studies through 3D laser scanning and thermographic technologies

Lagüela, S. *et al. Energy and Buildings*, 2011, 43, (6), 1218–1221.

Infrared thermography is generally used in energy efficiency studies in buildings, as well as in moisture detection studies and building inspections for heat losses. Commonly, thermographic studies are qualitative, based on detection of differences of temperature between points; and they only include thermal measurements on specific points or areas, associated to many other factors such as the thermal properties of the materials and environmental temperature and humidity. But this way of working presents a lot of limitations, as there is no way of executing precise quantitative measurements, because thermographic models are simple in geometry and thermographies include geometrical distortions introduced by the camera they are taken with. Laser scanning technology can be an optimal complement for the thermographic measurement, because it provides the metric information that allows the quantification of the thermal studies if the clouds of points are texturized with thermographies. In this paper a methodology for registering thermographies in clouds of points is explained, with the following steps: procedure for processing the metric calibration of the thermal camera, register of thermographies in the cloud of points based on control points, and finally, processing the textured cloud of points to obtain rectified thermographies, with no optical distortions.

12/00954 Entransy expression of the second law of thermodynamics and its application to optimization in heat transfer process

Liu, W. *et al. International Journal of Heat and Mass Transfer*, 2011, 54, (13–14), 3049–3059.

Based on theories of thermodynamics, the energy equation in terms of entransy in heat transfer process is introduced, which not only describes the change of entransy, but also defines the entransy consumption rate. According to the regularity of entransy change in heat transfer process and the effect of entransy consumption rate on the irreversibility of heat transfer process, it can be found that entransy is a state variable, from which a new expression for the second law of thermodynamics is presented. Then by setting entransy consumption rate and power consumption rate as optimization objective and constraint condition for each other, the Lagrange conditional extremum principle is used to deduce momentum equation, constraint equation and boundary condition for optimizing flow field of convective heat transfer, which are applied to simulate convective heat transfer coupling with energy equation in an enclosed cavity. Through the numerical simulation, the optimized flow field under different constraint conditions is obtained, which shows that the principle of minimum entransy consumption is more suitable than the principle of minimum entropy generation for optimizing convective heat transfer process.

12/00955 Error analysis of short term wind power prediction models

De Giorgi, M. G. *et al. Applied Energy*, 2011, 88, (4), 1298–1311.

The integration of wind farms in power networks has become an important problem. This is because the electricity produced cannot be preserved because of the high cost of storage and electricity production must follow market demand. Short-long-range wind forecasting over different lengths/periods of time is becoming an important process for the management of wind farms. Time series modelling of wind speeds is based upon the valid assumption that all the causative factors are implicitly accounted for in the sequence of occurrence of the process itself. Hence time series modelling is equivalent to physical modelling. Auto regressive moving average (ARMA) models, which perform a linear mapping between inputs and outputs, and artificial neural networks (ANNs) and adaptive neuro-fuzzy inference systems (ANFIS), which perform a non-linear mapping, provide a robust approach to wind power prediction. In this work, these models are developed in order to forecast power production of a wind farm with three wind turbines, using real load data and comparing different time prediction periods. This comparative analysis takes in the first time, various forecasting methods, time horizons and a deep performance analysis focused on the normalized mean error and the statistical distribution hereof in order to evaluate error distribution within a narrower curve and therefore forecasting methods whereby it is more improbable to make errors in prediction.

12/00956 Evaluation of image reconstruction algorithms for non-destructive characterization of thermal interfaces

Erturk, H. *International Journal of Thermal Sciences*, 2011, 50, (6), 906–917.

Thermal interfaces are encountered in many thermal management applications and interface materials are used to minimize thermal contact resistance resulting from solid–solid contact. For opto-electronic devices the quality of the thermal interface is critical for removing the generated heat for proper thermal management. Defects in the thermal interface introduce additional thermal resistance in the thermal path, and must be prevented. Detection of defects in the thermal interfaces becomes critical during the assembly process development. Imaging techniques such as X-ray computerized tomography, or scanning acoustic microscopy that require expensive equipment and significant processing time is necessary. Thermal tomography in conjunction to IR thermometry can be used as a lower cost alternative to these techniques. The feasibility of thermal tomography for non-destructive characterization of thermal interfaces is presented by considering different image reconstruction algorithms. The algorithms considered are the iterative perturbation algorithm, Levenberg–Marquardt algorithm and the regularized Newton–Gauss algorithm, and they were found to be capable of characterizing the thermal interface layer.

12/00957 Experimental study on the effect of magnetic field on the heat conductivity and viscosity of ammonia–water

Niu, X. *et al. Energy and Buildings*, 2011, 43, (5), 1164–1168.

External magnetic field may enhance the ammonia absorption in ammonia–water absorption refrigeration system. In this paper, the variations of viscosity and heat conductivity of magnetized ammonia–water are studied experimentally. The measured ammonia–water is magnetized by an electromagnet with magnetizing intensity from 132.64 to 261.35 mT. Different magnetization times including 10, 20 and 30 min are adopted. Engler viscosity measurement and transient double hot-wires measurement are used in the measurement of viscosity and heat conductivity respectively. The results show that the viscosity of ammonia–water solution decreases after magnetization, the decrease in viscosity is greater when the magnetic field is stronger and the magnetization time is longer. The heat conductivity of ammonia–water solution after magnetization increases with the prolonging of magnetization time and the increase of magnetizing intensity. It is not helpful to increase the heat conductivity of ammonia–water by increasing the magnetizing intensity and magnetization time unlimitedly. In the present experimental conditions, when the magnetization current is 8 A and the magnetization time is 30 min, the increase of the heat conductivity reaches the maximum. The variations of the viscosity and heat conductivity of magnetized ammonia–water may be attributable to Lorentz force and hydrogen bond breaking in microstructure.

12/00958 Investigated optical studies of Si quantum dot

Al-Douri, Y. *et al. Solar Energy*, 2011, 85, (9), 2283–2287.

Further study of the quantum dot potential for Si is presented. This potential has been calculated by means of the recent empirical model. The indirect energy gap (Γ–X) is calculated using the full potential-linearized augmented plane wave (FP-LAPW) method. The Engel–Vosko generalized gradient approximation (EV-GGA) formalism is used to optimize the corresponding potential for energetic transition and optical properties calculations of Si. The refractive index and transverse effective charge are predicted as a function of dot diameter that is in turn used to test the validity of this model. The obtained results show a reasonable agreement in comparison with experimental data and theoretical results.

12/00959 Laser diagnostics and minor species detection in combustion using resonant four-wave mixing

Kiefer, J. and Ewart, P. *Progress in Energy and Combustion Science*, 2011, 37, (5), 525–564.

Laser-based methods have transformed combustion diagnostics in the past few decades. The high intensity, coherence, high spectral resolution and frequency tunability available from laser radiation has provided powerful tools for studying microscopic processes and macroscopic phenomena in combustion by linear and non-linear optical processes. This review focuses on non-linear optical techniques based on resonant four-wave mixing for non-intrusive measurements of minor species in combustion. The importance of minor species such as reaction intermediates is outlined together with the challenges they present for detection and measurement in the hostile environments of flames, technical combustors, and engines. The limitations of conventional optical methods for such measurements are described and the particular advantages of coherent methods using non-linear optical techniques are discussed. The basic physics underlying four-wave mixing processes and theoretical models for signal calculation are then presented together with a discussion of how combustion parameters may be derived from analysis of signals generated in various four-wave mixing processes. The most important four-wave mixing processes, in this context, are then reviewed: degenerate four-wave mixing (DFWM), coherent anti-Stokes Raman scattering (CARS), laser induced grating spectroscopy (LIGS) and polarization spectroscopy (PS). In each case the fundamental physics is outlined to explain the particular properties and diagnostic advantages of each technique. The application of the methods mentioned to molecular physics studies of combustion species is then reviewed along with their application in measurement of concentration, temperature and other combustion parameters. Related non-linear techniques and recent extensions to the ultra-fast regime are briefly reviewed. Finally practical considerations relevant to multi-dimensional and multi-species measurements, as well as applications in technical combustion systems are discussed.

12/00960 Modeling choice of fuelwood source among rural households in Malawi: a multinomial probit analysis

Jumbe, C. B. L. and Angelsen, A. *Energy Economics*, 2011, 33, (5), 732–738.

This paper addresses two questions: what determines household's choice of fuelwood source and, what are the environmental consequences of fuelwood collection choices? These questions are addressed by estimating the multinomial probit model using survey data for households surrounding Chimaliro and Liwonde forest reserves in Malawi. After controlling for heterogeneity among households, strong substitution opportunities are found across fuelwood collection sources. Attributes of the fuelwood sources (size and species composition) and distance to the sources are the most important determinants of fuelwood choice. Further results show that customary managed forests generate environmental benefits by reducing pressure on both plantation forests and forest reserves. These findings support the need to strengthen community-based institutions to manage local forest resources.

12/00961 Numerical simulation of a partially buried pipeline in a permeable seabed subject to combined oscillatory flow and steady current

An, H. *et al. Ocean Engineering*, 2011, 38, (10), 1225–1236.

Hydrodynamic forces exerting on a pipeline partially buried in a permeable seabed subjected to combined oscillatory flow and steady current are investigated numerically. Two-dimensional Reynolds-averaged Navier–Stokes equations with a $k-\omega$ turbulent model closure are solved to simulate the flow around the pipeline. The Laplace equation is solved to calculate the pore pressure below the seabed with the simulated seabed hydrodynamic pressure as boundary conditions. The numerical model is validated against the experimental data of a fully exposed pipeline resting on a plane boundary under various flow conditions. Then the flow with different embedment depths, steady current ratios and KC numbers is simulated. The amplitude of seepage velocity is much smaller than the amplitude of free stream velocity as expected. The normalized Morison inertia, drag and lift coefficients based on the corresponding force coefficients of a fully exposed pipeline are investigated. The normalized Morison force coefficients reduce almost linearly with the increase of embedment depth and that the KC only has minor effect on the normalized Morison coefficients. It is also found that the permeable seabed condition causes a slight increase on the inline force and has a little effect on the lift force, compared with corresponding conditions in an impermeable bed.

12/00962 Possibilities and pitfalls in analyzing (upgraded) pyrolysis oil by size exclusion chromatography (SEC)

Hoekstra, E. *et al. Journal of Analytical and Applied Pyrolysis*, 2011, 91, (1), 76–88.

The applicability of size exclusion chromatography (SEC) to analyse (upgraded) pyrolysis oil samples has been studied using model compounds, pyrolysis oils and hydrodeoxygenated pyrolysis oils. The assumptions needed for the conversion of the chromatogram to the Mw-distribution were validated. It was shown that the conversion of elution volume to molecular weight (based on polystyrene calibration curves) can introduce substantial errors in the prediction of the molecular weight. The conversion of RID response to W (log M) (as plotted on the y-axis of the Mw-distribution) is based on the assumption of a compound independent RID response factor and linear response to concentration. While the latter was shown to be true within the concentration range studied, the former was not true: the RID response factor depends on the type of (upgraded) pyrolysis oil. It was shown that within a single pyrolysis oil sample, the RID response for the low molecular weight fraction was a factor of three lower than the high-molecular weight fraction. Furthermore long-term column fouling can influence SEC results that cannot be corrected with regular polystyrene recalibrations. Based on the results, SEC is not recommended to be used as a quantitative method for characterization (upgraded) pyrolysis oil samples, but as a tool to compare (upgraded) pyrolysis oil samples, preferably prepared using incremental operating conditions and expected to have similar molecular composition. This work has further shown that: (i) the $\int \mathrm{UVD}\, dv / \int \mathrm{RID}\, dv$ ratio can be used as an indication of the sum of the relative aromaticity and conjugated double bond content for (upgraded) pyrolysis oil, and (ii) the negative peak area appearing in the low molecular weight part of the chromatogram can be used to estimate the water content of (upgraded) oil samples.

12/00963 Producing ashless coal extracts by microwave irradiation

Sönmez, Ö. and Giray, E. S. *Fuel*, 2011, 90, (6), 2125–2131.

To produce ashless coal extracts, three Turkish coals were extracted with *N*-methyl-2-pyrrolidinone (NMP), NMP/ethylenediamine (EDA) (17/1, vol/vol) mixture and NMP/tetralin (9/1, vol/vol) mixture through thermal extraction and microwave extraction. Solvent extraction by microwave irradiation (MI) was found to be more effective than that by thermal extraction. Extraction yield of coals in NMP enhanced by addition of a little EDA, but tetralin addition showed variances according to extraction method used. While tetralin addition caused a decrease in the thermal extraction yield, it increased the yield of the extraction by MI. Following the extraction, the solid extracts were produced with ash content ranging from 0.11% to 1.1%. Ash content of solid extract obtained from microwave extraction are less than ash contents of solid extracts obtained from thermal extraction.

12/00964 Raman spectroscopy study of molecular hydrogen solubility in water at high pressure

Ziparo, C. *et al. International Journal of Hydrogen Energy*, 2011, 36, (13), 7951–7955.

The authors have measured the Raman spectra of gaseous molecular hydrogen dissolved in liquid water at room temperature and as a function of pressure. Vibrational spectra of molecular hydrogen have been clearly detected. Band intensities and profiles have been carefully measured using, for calibration purposes, the water OH stretching band. From the measured intensities of the Raman band, the authors have obtained the behaviour of hydrogen concentration in the liquid water, as a function of the gas partial pressure. The observed behaviour is presented and compared to Henry's law predictions. Additionally, a detailed analysis is presented of the spectral band features from which important information on the interaction of hydrogen with water molecules could be derived.

12/00965 Review of building energy-use performance benchmarking methodologies

Chung, W. *Applied Energy*, 2011, 88, (5), 1470–1479.

This paper reviews the mathematical methods used in developing benchmarking systems, to discuss the properties of the methods, and to classify two kinds of benchmarking systems based on their properties. It was found that while benchmarking systems are developed by using the energy-use performance of a significant number of reference buildings, benchmarking results can be used to encourage poor reference performers (in energy-efficiency) to improve their performance. On the other hand, because benchmarking systems also function as a public yardstick of energy-use performance in buildings, some regulators release benchmarking information to the media. This proves advantageous because it brings public pressure on owners/developers of poorly performing non-reference buildings. However, not all benchmarking systems can be used by public users (i.e. other non-reference building owners). Depending on whether the resulting benchmarking system can be used in public, the authors note that there are two kinds of benchmarking system: public benchmarking and internal benchmarking. These two types of benchmarking system are developed by different methods.

12/00966 Simplex ray-object intersection algorithm as ray tracer for Monte Carlo simulations in radiative heat transfer analysis

Naeimi, H. and Kowsary, F. *International Communications in Heat and Mass Transfer*, 2011, 38, (5), 646–651.

In the thermal radiation analysis via the Monte Carlo method, considerable computational resources are consumed to find the intersection point of an emitted energy bundle with radiant enclosure walls. Therefore, an efficient algorithm for ray-object intersection in complex geometries may cause saving time and computational effort. This paper presents a new ray-object intersection algorithm based on the well-known simplex method from linear programming. This algorithm works by searching a point in the feasible region which is defined by a set of plane equations of enclosure boundaries that maximize the line equation of the emitted energy bundle as the objective function. This algorithm is examined for two benchmark problems, namely two parallel plates with grey specular surfaces and a box with grey diffuse walls both in three-dimensional case. Although the computation time of the new proposed method is a bit higher than the conventional time, it is easy to implement because simplex algorithm is readily available as separate module in most programming languages. By using this algorithm number of objects which must be checked in complex geometries will be reduced considerably.

12/00967 Spatially explicit modelling of biofuel crops in Europe

Hellmann, F. and Verburg, P. H. *Biomass and Bioenergy*, 2011, 35, (6), 2411–2424.

This paper describes a methodology to explore the (future) spatial distribution of biofuel crops in Europe. Two main types of biofuel crops are distinguished: biofuel crops used for the production of biodiesel or bioethanol, and second-generation biofuel crops. A multi-scale, multi-model approach is used in which biofuel crops are allocated over the period 2000–2030. The area of biofuel crops at the national level is determined by a macro-economic model. A spatially explicit land use model is used to allocate the biofuel crops within the countries. Four scenarios have been prepared based on storylines influencing the extent and spatial distribution of biofuel crop cultivation. The allocation algorithm consists of two steps. In the first step, processing plants are allocated based on location factors that are dependent on the type of biofuel crop processed and scenario conditions. In the second step, biofuel crops are allocated accounting for the transportation costs to the processing plants. Both types of biofuel crops are allocated separately based on different location factors. Despite differences between the scenarios, mostly the same areas are showing growth in biofuel crop cultivation in all scenarios. These areas stand out because they have a combination of well-developed infrastructural and industrial facilities and large areas of suitable arable land. The spatially explicit results allow an assessment of the potential consequences of large-scale biofuel crop cultivation for ecology and environment.

12/00968 The energy-saving characteristic of silica gel regeneration with high-intensity ultrasound

Zhang, W. *et al. Applied Energy*, 2011, 88, (6), 2146–2156.

The energy-saving characteristic of silica gel regeneration with power ultrasonic was analysed by introducing the conception of specific energy consumption. For the purpose, the experiments of silica gel regeneration with 21-kHz power ultrasound were performed under different drying air temperatures (i.e. 35, 45, 55 and 65 °C) combined with different acoustic power levels (i.e. 0, 20, 40 and 60 W). And the energy saving ratios of the ultrasonic-assisted regeneration were studied by the method of ANOVA (analysis of variance) and compared among different conditions. The influences of acoustic power and drying air temperature as well as the target moisture ratio (at which the regeneration process ended) on the total specific energy consumption (TSEC) and the excess specific energy consumption (ESEC) were also discussed. The results indicate that all the factors (drying temperature, ultrasonic power level and the interaction between the drying temperature and the power level) have a significant ($P > 0.05$) influence on the energy saving ratio, among which the influence of drying temperature is the most significant ($P > 0.05$). According to the analysis of specific energy consumption, the optimal drying conditions aiming at the minimum energy use can be obtained. For the present experimental conditions, the condition of 55 °C (drying temperature) and 60 W (acoustic power level) can achieve the lowest TSEC and ESEC. In addition, different thresholds of power level are required to achieve the energy-saving effect due to the application of ultrasonic in the regeneration. The method of specific energy consumption can be also used for the energy analysis of the new regeneration technology in the scale-up study.

12/00969 Thermal analysis of a spent fuel cask in different transport conditions

Lo Frano, R. *et al. Energy*, 2011, 36, (4), 2285–2293.

Like all industries, the generation of electricity from nuclear power plants produces wastes to be managed. Spent fuel element casks used for transport of nuclear materials must be designed according to rigorous acceptance criteria and standards requirements, e.g. International Atomic Energy Agency ones, in order to provide protection to people and environment against radiation exposure. The aim of this work was the evaluation of the integrity of spent fuel cask under both normal and accident transport conditions, such as impact (9 m drop impact event onto a flat, essentially unyielding, horizontal surface, in the most damaging orientation) and rigorous fire events (full exposure to an engulfing fire for 30 min (fire test) or to an environment at 800 °C temperature for a numerical simulation or for a furnace test). Using the finite element code ANSYS both steady-state and transient thermal analyses were carried out to determine the maximum fuel temperature and the temperatures behaviour into the cask, considering all the heat transfer modes between the cask and the external environment as well as inside the cask itself. Moreover, both wet and dry fuel storage inside the cavity of the body were analysed. The obtained results, used for the new licensing approval by the Italian competent authority of the cask for PWR spent fuel transport, are discussed.

12/00970 Towards a predictive evaporation model for multi-component hydrocarbon droplets at all pressure conditions

Ebrahimian, V. and Habchi, C. *International Journal of Heat and Mass Transfer*, 2011, 54, (15–16), 3552–3565.

In this paper, a new evaporation model for multi-component hydrocarbon droplets is proposed. Compared to previously published models, it has two new features. First, an expression of the Stefan velocity is proposed which ensures gas mass conservation. In addition, the evaporation rate of each species is obtained by the integration of the exact equation of species mass fraction. Second, the heat flux due to species diffusion is taken into account in addition to the classical conduction heat flux between the gas and the liquid droplets. The comprehensive multi-component droplets vaporization model including the above two features is presented for high and low pressure conditions, for which a real and a perfect fluid equation of state (EOS) has been used, respectively. Free convection is also taken into account using the Grashof number in the Kulmala–Vesala correlations for the Sherwood and Nusselt numbers. The model is compared with very accurate experimental data obtained elsewhere at atmospheric pressure and temperature ranges of 473–973 K for n-heptane and 548–623 K for n-decane droplets of 400 μm initial size. A very good agreement with the experimental data including micro-gravity conditions has been obtained. Indeed, the results have confirmed that the free convection process plays a significant role in the evaporation rate of liquid droplets under earth gravity and quiescent conditions. This shows the

relevance of the new features of the model. The numerical results have also shown that real fluid EOS is not necessary at atmospheric pressure for the temperature range given above. In addition, the numerical results of the new model are also compared with the experimental data for two-component droplets of n-heptane and n-decane with different compositions of the liquid mixture. Finally, the non-ideality of the mixture is shown to become significant at high ambient pressures and especially at low ambient temperature conditions where a real-gas EOS is needed.

Fuel cell technology

12/00971 A mass integration concept for high temperature fuel cell plants

Hartono, B. *et al. International Journal of Hydrogen Energy*, 2011, 36, (12), 7240–7250.

The authors investigate the utilization of anode exhaust gas from high temperature fuel cells as gasification or reforming agent in solid oxide fuel cell (SOFC) and molten carbonate fuel cell (MCFC) power plants. The minimal anodic recirculation ratio is determined by two approaches: based on stoichiometric considerations and using detailed modelling of all process units. In the latter case, the risk of carbon formation and system heat integration are considered. The results indicate that the stoichiometric approach can be used as a shortcut method only for the SOFC systems due to good agreements with the detailed calculations. Furthermore, the mass integration concept is a feasible option for a wide variety of fuels in SOFC plants thanks to their relatively high operating temperatures. In MCFC systems, significantly higher recycle ratios are required to suppress carbon deposition which makes this concept unattractive.

12/00972 A method for evaluating the efficiency of PEM fuel cell engine

Hou, Y. P. *et al. Applied Energy*, 2011, 88, (4), 1181–1186.

Efficiency is an important factor to reflect the performance of fuel cell engine (FCE). Evaluating efficiency should consider efficiency properties and common work conditions of FCE. In this paper, output power of FCE on real work conditions is analysed according to driving cycles, and four efficiency evaluation points are obtained, as well as their weighted values. Then, a scoring function is used to convert the efficiency values of four evaluation points into scores. Multiplying scores by their weighted values and adding them together, overall scores of efficiency properties can be obtained. This method can evaluate the efficiency performance of FCE reasonably and objectively.

12/00973 A multi-scale approach to material modeling of fuel cell diffusion media

Becker, J. *et al. International Journal of Heat and Mass Transfer*, 2011, 54, (7–8), 1360–1368.

Effective diffusivity of porous media in fuel cells has been identified as a relevant material property in automotive applications. Pore-scale simulations utilizing imaging data sets of real materials or virtual model representations provide such diffusivity numbers. However, components like the microporous layer (MPL) or the gas diffusion electrode have not been covered adequately so far by efficient and practical modelling approaches due the small pore sizes and resulting Knudsen contribution to diffusion. This paper reports the development of a numerical method which allows for the determination of binary diffusion coefficients for all Knudsen numbers and demonstrate the application to fuel cell diffusion media in a multi-scale modelling approach. For high Knudsen numbers effective diffusivity is determined by tracking a large number of individual molecules that collide with the pore walls. For low Knudsen numbers, effective diffusivity is determined by solving the Laplace equation on the pore space. Both contributions to the overall diffusivity are merged by applying Bosanquet's formula. The resulting diffusivity can be used as an effective number for a microporous layer coating of a spatially resolved fibrous diffusion medium. As this multi-scale method is also based on a 3D voxel grid, any distribution of the MPL on and inside the gas diffusion layer (GDL) could be studied with this model, e.g. cracks, different penetration depths, etc.

12/00974 A review of polymer electrolyte membrane fuel cells: technology, applications, and needs on fundamental research

Wang, J. *et al. Applied Energy*, 2011, 88, (4), 981–1007.

Significant progress has been made in the past few years in polymer electrolyte membrane fuel cell (PEMFC) technology, and the current status of PEMFC technology in durability and cost can be summarized as follows. (1) The US Department of Energy (DOE) target of durability lifetime is greater than 5000 h for transportation applications by 2015 and 40,000 h for stationary applications by 2011. Currently, approximately 2500 h of lifetime was achieved in 2009 for transportation and 20,000 h was obtained in 2005 for stationary fuel cells. (2) The DOE target of cost is \$45/kW in 2010 and \$30/kW in 2015 for transportation applications and \$750/kW by 2011 for stationary applications. The current cost is \$61/kW in 2009 for transportation fuel cells. To further overcome the barriers to the wide deployment of fuel cells, fundamental breakthroughs are needed. This review briefly discusses the role and summarizes the needs on fundamental research as well as the associated challenges. Aspects of materials development, acquisition of fundamental knowledge, and development of analytical models and experimental tools are required. Improvement on catalyst, membrane electrode assembly (MEA) components, and bipolar plates are particularly important for overcoming the two major commercialization barriers (i.e. durability and cost). Specially, for the membrane and catalyst layers (which consist of the MEA), both require significant further research in order to identify and develop alternative cost-effective materials. Correlations of membrane properties to performance for general polymer electrolyte materials are much in need. MEAs with better degradation resistance and low Pt loading are critical to achieving the DOE cost and lifetime targets. For gas diffusion layers (GDLs) and micro-porous layers (MPLs), a fundamental understanding of liquid-water behaviours in these components is required, in particular on the effects of the micro structure of the media and the proper combination of hydrophobicity and hydrophilicity. For bipolar plates and gas flow channels (GFCs), advanced fabrication methods are needed to reduce the cost of the plates and improve their corrosion resistance. Lastly, fundamental knowledge of liquid droplet removal at the GDL/GFC interfaces and two-phase flow in micro-/mini-channels is challenging to obtain, but is needed urgently to develop optimized GDL materials and GFC designs that can ensure efficient water removal and reactant supply and avoid flow maldistribution and thus maintain high fuel-cell performance.

12/00975 A single-component fuel cell reactor

Zhu, B. *et al. International Journal of Hydrogen Energy*, 2011, 36, (14), 8536–8541.

Reported here is a single-component reactor consisting of a mixed ionic and semi-conducting material exhibiting hydrogen-air (oxygen) fuel cell reactions. The new single-component device was compared to a conventional three-component (anode/electrolyte/cathode) fuel cell showing at least as good performance. A maximum power density of 300–600 $mW\,cm^{-2}$ was obtained with a LiNiZn-oxide and ceria-carbonate nanocomposite material mixture at 450–550 °C. Adding a redox catalyst element (Fe) resulted in an improvement reaching 700 $mW\,cm^{-2}$ at 550 °C.

12/00976 Analysis of 3000 T class submarines equipped with polymer electrolyte fuel cells

Ghosh, P. C. and Vasudeva, U. *Energy*, 2011, 36, (5), 3138–3147.

The naval submarines have conventionally been equipped with diesel-electric propulsion. The diesel generators charge the batteries when the submarine is at the surface or at snorkelling depth. This is the biggest short-coming of this system as the submarine can be detected due to the infrared signatures from the exhaust of engines. Present study aims in analysing the feasibility of using fuel cells as a replacement of conventional diesel based system. Fuel cell system is analysed to meet the propulsion load and hotel load. In this purpose, metal hydride and sodium borohydride are considered for fuel and compressed oxygen and liquid oxygen are considered as oxidant. The most effective combination with respect to weight, volume has been analysed. The submerged endurance and distance for various hotel loads under submerged conditions have also been estimated. It is found that the metal hydride and liquid oxygen combination can be easily retrofitted by replacing the conventional system. However, MH/O_2, SBH/O_2 and SBH/LO_X require some extra room to be created. All the systems show substantial enhancement in the submerged endurance.

12/00977 Artificial immune system-based parameter extraction of proton exchange membrane fuel cell

Askarzadeh, A. and Rezazadeh, A. *International Journal of Electrical Power & Energy Systems*, 2011, 33, (4), 933–938.

For a better understanding of the characteristics, performance evaluation and design analysis of proton exchange membrane fuel cell (PEMFC) system an accurate mathematical model is an imperative tool. Although various models have been developed in the literature, because of the shortage of manufacture information about the precise values of the parameters required for the modelling, the parameter extraction is an essential task. So, in order to obtain the PEMFC actual performance, its parameters have to be identified by an optimization technique. Artificial immune system (AIS) is a soft computing method with promising results in the field of optimization problems. In this paper, an AIS-based algorithm for parameter identification of a PEMFC stack model is proposed. In order to study the usefulness of the proposed algorithm, the AIS-based results are compared with the

obtained results by the genetic algorithm (GA) and particle swarm optimization (PSO). It is shown that the AIS algorithm is a helpful and reliable technique for identifying the model parameters so that the PEMFC model with extracted parameters agrees with the experimental data well. Moreover, the AIS algorithm outperforms the GA and PSO methods. Therefore, the AIS can be applied to solve other complex identification problems of fuel cell models.

12/00978 Control oriented modeling of ejector in anode gas recirculation solid oxygen fuel cell systems

Zhu, Y. *et al. Energy Conversion and Management*, 2011, 52, (4), 1881–1889.

A one-equation model is proposed for fuel ejector in anode gas recirculation solid oxide fuel cell (SOFC) system. Firstly, the fundamental governing equations are established by employing the thermodynamic, fluid dynamic principles and chemical constraints inside the ejector; secondly, the one-equation model is derived by using the parameter analysis and lumped-parameter method. Finally, the computational fluid dynamics (CFD) technique is employed to obtain the source data for determining the model parameters. The effectiveness of the model is studied under a wide range of operation conditions. The effect of ejector performance on the anode gas recirculation SOFC system is also discussed. The presented model, which only contains four constant parameters, is useful in real-time control and optimization of fuel ejector in the anode gas recirculation SOFC system.

12/00979 Crosslinked sulfonated poly(arylene ether ketone) membranes bearing quinoxaline and acid–base complex cross-linkages for fuel cell applications

Chen, X. *et al. Journal of Power Sources*, 2011, 196, (4), 1694–1703.

A series of crosslinkable sulfonated poly(arylene ether ketone)s (SPAEKs) were synthesized by copolymerization of 4,4′-biphenol with 2,6-difluorobenzil and 5,5′-carbonyl-bis(2-fluorobenzene-sulfonate). A facile crosslinking method was successfully developed, based on the cyclocondensation reaction of benzil moieties in polymer chain with 3,3′-diaminobenzidine to form quinoxaline groups acting as covalent and acid–base ionic crosslinking. The uncross-linked and cross-linked SPAEK membranes showed high mechanical properties and the isotropic membrane swelling, while the later became insoluble in tested polar aprotic solvents. The crosslinking significantly improved the membrane performance, i.e. the cross-linked membranes had the lower membrane dimensional change, lower methanol permeability and higher oxidative stability than the corresponding precursor membranes, with keeping the reasonably high proton conductivity. The crosslinked membrane (C-B4) with an ion exchange capacity of 2.02 mequiv. g^{-1} showed a reasonably high proton conductivity of 111 mS cm^{-1} with a low water uptake of 42 wt% at 80 °C. C-B4 exhibited a low methanol permeability of 0.55×10^{-6} cm^2 s^{-1} for 32 wt% methanol solution at 25 °C. The cross-linked SPAEK membranes have potential for PEFC and DMFC applications.

12/00980 Design layout of hydrogen research and development garage

Thomas, M. *et al. International Journal of Hydrogen Energy*, 2011, 36, (13), 8017–8022.

Research and development programs toward fuel cells and other hydrogen technologies have increased significantly during the past two decades. These programs require appropriate facilities to undertake the research and development programs. This paper discusses the design layout of one such facility, the 'Missouri S&T EcoCAR Hydrogen Vehicle Garage', which can be used as a model while designing a hydrogen R&D garage. The Missouri S&T EcoCAR garage is a 12.2 m × 7.6 m garage situated at the Missouri University of Science and Technology (Missouri S&T) and serves as the headquarters for the Missouri S&T EcoCAR team. Within the garage, students will gain real-world, hands-on experience by transforming a standard production vehicle into a hydrogen fuel cell plug-in hybrid electric vehicle (FC-PHEV). The garage is classified as a Class 1 Division 2, Group B hazardous location and is equipped to safely test and integrate the vehicle prototype. Specifically, the design includes: (i) a hydrogen gas detection system, (ii) hazardous location electrical service, heating, ventilation and air-conditioning, lighting, and compressed air systems, and (iii) emergency backup electric power system with alarms/monitors/security cameras for the hydrogen R&D facility. The garage will be connected to an external backup power supply unit which will be powered by a PEM fuel cell.

12/00981 Electrolytic effect in solid oxide fuel cells running on steam/methane mixture

Ni, M. *Journal of Power Sources*, 2011, 196, (4), 2027–2036.

A two-dimensional model is developed to study the performance of a planar solid oxide fuel cell (SOFC) running on steam/methane mixture. The model considers the heat/mass transfer, electrochemical reactions, direct internal reforming of methane (CH_4), and water gas shift reaction in an SOFC. It is found that at an operating potential of 0.8 V, the upstream and downstream of SOFC work in electrolysis and fuel cell modes, respectively. At the open-circuit voltage, the electricity generated by the downstream part of SOFC is completely consumed by the upstream through electrolysis, which is contrary to the common understanding that electrochemical reactions cease under the open-circuit conditions. In order to inhibit the electrolytic effect, the SOFC can be operated at a lower potential or use partially pre-reformed CH_4 as the fuel. Increasing the inlet gas velocity from 0.5 m s^{-1} to 5.0 m s^{-1} does not reduce the electrolytic effect but decreases the SOFC performance.

12/00982 Experimental study on the hydrogen production of integrated methanol-steam reforming reactors for PEM fuel cells

Chein, R.-Y. *et al. International Journal of Thermal Sciences*, 2011, 50, (7), 1253–1262.

A 60 mm × 50 mm × 12 mm stainless steel compact reactor for hydrogen production from methanol-steam reforming (MSR) is presented. The proposed design was constructed by integrating vaporizer, reformer and combustor into a single unit. The energy required for the MSR is provided by heat generated from platinum (Pt)-catalytic methanol combustion in the combustor. $CuO/ZnO/Al_2O_3$ is used as the catalyst for the MSR. Three different reformer designs: patterned microchannel with catalyst coated onto the channel wall; single plain channel with catalyst coated onto the bottom channel wall, and inserted stainless mesh layer coated with catalyst, are experimentally tested to identify the flow and heat transfer effects on the reactor performance. The experimental results show that the methanol conversion using reformer with patterned microchannel is about 15% higher than that obtained using the reformer with inserted catalyst layer which has the lowest methanol conversion among the three reformers studied. The experimental results also show that the reactor with microchannel reformer has the best thermal efficiency among the three designs. This indicated that more effective heat and mass transfers provided by the microchannel can produce higher methanol conversion. Although the reformer with inserted catalyst layer exhibited performance lower than the reformer with patterned microchannel, it provides convenience in catalyst replacement when the catalyst is aged from the practical application point of view.

12/00983 Hybrid electric system based on fuel cell and battery and integrating a single dc/dc converter for a tramway

Fernandez, L. M. *et al. Energy Conversion and Management*, 2011, 52, (5), 2183–2192.

This paper presents a hybrid electric power system for a real surface tramway. The hybrid system consists of two electrical energy sources integrating a single dc/dc converter to provide the power demanded by the tramway loads (four electric traction motors and auxiliary services): (1) a polymer electrolyte membrane (PEM) fuel cell (FC) as the primary and (2) a rechargeable Ni–MH battery as electrical energy storage to supplement the FC over the driving cycle. According to the requirements of the real driving cycle of the tramway, it was considered a 200 kW PEM FC system with two FCs connected in parallel and a 34 Ah Ni–MH battery. The PEM FC and Ni–MH battery models were designed from commercially available components. The power conditioning system provides the appropriate power for the tramway. It is composed of: (1) a unique dc/dc boot converter which adapts the FC output voltage to the 750 V traction standard dc bus; (2) three-phase inverters to drive properly each electric motors; and (3) a braking chopper to dissipate excess of regenerative braking energy. Suitable state machine control architecture is presented for the hybrid system, its objective being to provide demanded power by the driving cycle, optimizing the energy generated. Following this objective, a new state machine control strategy based on eight states decides the operating point of each component of the system and a cascade control structure allows achieving the operating points determined by the strategy. Simulation results of the real driving cycle of the tramway check the adequacy of the hybrid electric power system.

12/00984 Nonlinear control of fuel cell hybrid power sources: part I – voltage control

Bizon, N. *Applied Energy*, 2011, 88, (7), 2559–2573.

In this paper a non-linear control for fuel cell/battery/ultracapacitor hybrid power sources (HPS) is proposed that improves the performance and durability of fuel cell. The non-linear voltage control is analysed and designed using a systematic approach. The design goal is to stabilize the HPS output voltage at a low voltage ripple that is also spread in a large frequencies band. All the results have been validated in several simulations. The simulation results successfully show that non-linear voltage control performs good performances in the frequency-domain (a high spreading level of power spectrum) and in the time domain (a low level of output voltage ripple factor), too.

12/00985 Nonlinear control of fuel cell hybrid power sources: part II – current control
Bizon, N. *Applied Energy*, 2011, 88, (7), 2574–2591.
In this paper is proposed a non-linear current-mode control for the fuel cell/battery/ultracapacitor hybrid power sources (HPS) that improves the ripple factor of the fuel cell current. The non-linear current control is analysed and designed using a systematic approach. The design goal is to generate an anti-ripple via buck current controlled source in order to mitigate the inverter current ripple. All the results have been validated in several simulations. The simulation results successfully show that non-linear current-mode control determines in the low frequency-domain better performances than other current-mode control techniques, such as the hysteretic current-mode controller or the peak current-mode controller. The current ripple factor is one of the used performance indicators.

12/00986 Passive direct methanol fuel cells for portable electronic devices
Achmad, F. *et al. Applied Energy*, 2011, 88, (5), 1681–1689.
Due to the increasing demand for electricity, clean, renewable energy resources must be developed. Thus, the objective of the present study was to develop a passive direct methanol fuel cell (DMFC) for portable electronic devices. The power output of six dual DMFCs connected in series with an active area of 4 cm^2 was approximately 600 mW, and the power density of the DMFCs was 25 $mW\,cm^{-2}$. The DMFCs were evaluated as a power source for mobile phone chargers and media players. The results indicated that the open circuit voltage of the DMFC was between 6.0 V and 6.5 V, and the voltage under operating conditions was 4.0 V. The fuel cell was tested on a variety of cell phone chargers, media players and PDAs. The cost of energy consumption by the proposed DMFC was estimated to be US\$20 W^{-1}, and the cost of methanol is US\$4 kW h. Alternatively, the local conventional electricity tariff is US\$2 kW h. However, for the large-scale production of electronic devices, the cost of methanol will be significantly lower. Moreover, the electricity tariff is expected to increase due to the constraints of fossil fuel resources and pollution. As a result, DMFCs will become competitive with conventional power sources.

12/00987 Strategies for optimizing the opening of the outlet air circuit's nozzle to improve the efficiency of the PEMFC generator
Tirnovan, R. *et al. Applied Energy*, 2011, 88, (4), 1197–1204.
The aim of this study is the optimal dimensioning of the air circuit's outlet nozzle in relation with the load duration curve, for a given PEMFC generator, in order to maximize the PEMFC efficiency and to increase the net outlet power. The steady state PEMFC operation has been taken into account. The model of the PEMFC system used in the work is based on a moving least-squares technique. A centrifugal compressor has been taken into account, and the operating line of the compressor has been evaluated for an optimal fixed opening of the outlet nozzle. A multi-level optimization procedure has been implemented to solve the optimization problem. The developed algorithm is useful to design an optimum air subsystem, reducing the number of the control variables and the consequences of the dynamic behaviour of a controlled electric adjustable valve on the PEMFC performance. The results of the work can contribute to the improvement of the PEMFC generator reliability and of its cost/performance ratio.

12/00988 Strategies for stationary and portable fuel cell markets
Cottrell, C. A. *et al. International Journal of Hydrogen Energy*, 2011, 36, (13), 7969–7975.
In the future, hydrogen-based stationary and portable fuel cell systems can help supply some or all of the power demanded with additional advantages of higher reliability, lower emissions, independence from the general grid, and cogeneration capability. In order to understand how to prepare the future for this technology, this paper describes a thorough investigation of past alternative stationary and portable power projects in order for an assessment of the opportunities for stationary and portable fuel cell markets, as well as interactions with transportation hydrogen systems. The lessons learned from the programs are used to establish best practices and recommendations for a hydrogen strategy that addresses opportunities for hydrogen in power generation systems, as well as to make recommendations for market transformation within the hydrogen fuel cell industry.

12/00989 Thermo-electrical instabilities arising in proton exchange membrane of fuel cell
Bograchev, D. A. and Martemianov, S. *International Journal of Heat and Mass Transfer*, 2011, 54, (13–14), 3024–3030.
A thermo-electrical model of fuel cell proton exchange membrane is developed and the stability of the system is studied. The marginal curves have been obtained as a function of governed dimensionless parameters. The determined dimensionless parameters allow analysing different scenarios of non-controlled membrane heating. It has been shown that a positive thermo-electrical feedback can cause instability development and membrane damage in real systems. Recommendations for the improvement of heat management in fuel cells have been proposed using the provided stability study. In particular, it has been demonstrated that decreasing of gas diffusion layer thickness has positive effect and stabilizes the system.

12/00990 Transient response of PEM fuel cells with parallel and interdigitated flow field designs
Wang, X.-D. *et al. International Journal of Heat and Mass Transfer*, 2011, 54, (11–12), 2375–2386.
Transient characteristics of proton exchange membrane (PEM) fuel cells with parallel and interdigitated flow fields upon changes in voltage load were investigated by applying a three-dimensional, two-phase model. Effects of channel to rib width ratios and cathode inlet flow rates on the transient response of PEM fuel cell were examined in detail. Current overshoot and undershoot occur because the time scale for the voltage change is much shorter than for the oxygen concentration changes. Therefore, the oxygen concentrations on the cathode diffusion layer-catalyst layer interface immediately after the voltage changes are essentially the same as before the voltage changes, which results in higher reaction rates causing overshoots when the voltage decreases or lower reaction rates causing undershoots when the voltage increases. The predictions also show that as the voltage decrease rate is reduced, the overshoot peak weakens and the response time shortens. Since the interdigitated flow field has higher oxygen concentrations on the cathode diffusion layer-catalyst layer interface due to the forced convection, the overshoot peaks and the undershoot valleys are all greater than for the parallel flow field. For both flow fields, larger channel to rib width ratios cause larger overshoots, smaller undershoots and longer response times.

15 ENVIRONMENT

Pollution, health protection, applications

12/00991 A Swedish environmental rating tool for buildings
Malmqvist, T. *et al. Energy*, 2011, 36, (4), 1893–1899.
In 2003, a joint effort between the Swedish government, a number of companies in the building and construction sectors, some municipalities, insurance companies and banks set a target that by 2009, all new buildings and 30% of existing Swedish buildings should be rated using a voluntary environmental rating tool. In a major research programme finished in 2008, a tool was developed to be used in this context. The tool covers three assessment areas: energy, indoor environment and material & chemicals. These areas are split into 11 aspects with one or a few indicators. Rating criteria are specified for each indicator, stipulating requirements for a rating Gold, silver, bronze and rated. Indicator results can then be aggregated to aspect, area and a single rating for building level for enhanced result communication. The tool builds on previous experiences regarding environmental building rating tools and therefore includes some special characteristics that aim to tackle some of the criticism directed towards the first generation of such tools. At the time of writing, the first buildings have received official ratings and an independent stakeholder group is promoting broader implementation of the tool.

12/00992 A systematic procedure to study the influence of occupant behavior on building energy consumption
Yu, Z. *et al. Energy and Buildings*, 2011, 43, (6), 1409–1417.
Efforts have been devoted to the identification of the impacts of occupant behaviour on building energy consumption. Various factors influence building energy consumption at the same time, leading to the lack of precision when identifying the individual effects of occupant behaviour. This paper reports the development of a new methodology for examining the influences of occupant behaviour on building energy consumption; the method is based on a basic data mining technique (cluster analysis). To deal with data inconsistencies, min–max normalization is performed as a data preprocessing step before clustering. Grey relational grades, a measure of relevancy between two factors, are used as weighted coefficients of different attributes in cluster analysis. To demonstrate the applicability of the proposed method, the method was applied to a set of residential buildings' measurement data. The results show that the method facilitates the evaluation of building energy-saving potential by improving the behaviour of building

occupants, and provides multifaceted insights into building energy end-use patterns associated with the occupant behaviour. The results obtained could help prioritize efforts at modification of occupant behaviour in order to reduce building energy consumption, and help improve modelling of occupant behaviour in numerical simulation.

12/00993 Actuarial risk assessment of expected fatalities attributable to carbon capture and storage in 2050

Ha-Duong, M. and Loisel, R. *International Journal of Greenhouse Gas Control*, 2011, 5, (5), 1346–1358.

This study estimates the human cost of failures in the CCS industry in 2050, using the actuarial approach. The range of expected fatalities is assessed integrating all steps of the CCS chain: additional coal production, coal transportation, carbon capture, transport, injection and storage, based on empirical evidence from technical or social analogues. The main finding is that a few hundred fatalities per year should be expected if the technology is used to avoid emitting $3.67\,GtCO_2\ year^{-1}$ in 2050 at baseload coal power plants. The large majority of fatalities are attributable to mining and delivering more coal. These risks compare to today's industrial hazards: technical, knowable and occupational dangers for which there are socially acceptable non-zero risk levels. Some contemporary European societies tolerate about one fatality per thousand years around industrial installations. If storage sites perform like that, then expected fatalities per year due to leakage should have a minor contribution in the total expected fatalities per year: less than one. But to statistically validate such a safety level, reliability theory and the technology roadmap suggest that CO_2 storage demonstration projects over the next 20 years have to cause exactly zero fatality.

12/00994 Behavioural, physical and socio-economic factors in household cooling energy consumption

Yun, G. Y. and Steemers, K. *Applied Energy*, 2011, 88, (6), 2191–2200.

As global warming continues, the current trend implies that the uptake of air conditioning in the residential sector will go up, thus potentially increasing domestic cooling energy consumption. In this context, this paper investigates the significance of behavioural, physical and socio-economic parameters on cooling energy in order to improve energy efficiency in residential buildings. It demonstrates that such factors exert a significant indirect as well as direct influence on energy use, showing that it is particularly important to understand indirect relationships. An initial study of direct factors affecting cooling energy reveals that occupant behaviour is the most significant issue (related to choices about how often and where air conditioning is used). This is broadly confirmed by path analysis, although climate is seen to be the single most significant parameter, followed by behavioural issues, key physical parameters (e.g. air conditioning type), and finally socio-economic aspects (e.g. household income).

12/00995 Bio-energy and youth: analyzing the role of school, home, and media from the future policy perspectives

Halder, P. *et al. Applied Energy*, 2011, 88, (4), 1233–1240.

The study investigated the relationships between students' perceived information on bio-energy from school, home and media and their perceptions, attitudes, and knowledge regarding bio-energy. The study also analysed the scope of future policies to raise awareness among young students about bio-energy. Data drawn from 495 Finnish students studying in ninth grade revealed that the students were more positive in their attitudes towards bio-energy compared to their perceptions of it. They were very positive about learning about bio-energy, while not so eager towards its utilization. It appeared that school, home, and media all had statistically significant effects on students' perceptions, attitudes, and level of knowledge related to bio-energy. Three principal components emerged from students' perceptions and attitudes towards bio-energy, namely 'motivation' revealing students' eagerness to know more about bio-energy; 'considering sustainability' revealing their criticality of forest bio-energy; and 'utilization' revealing their state of interests to use bio-energy. Bio-energy policies to be effective must consider the role of school, home, and media as important means to engage young students in bio-energy related discussions. It is also desirable to establish interactions between energy and educational policies to integrate the modern renewable energy concepts in the school curriculum.

12/00996 Designing a friendly space for technological change to slow global warming

Nordhaus, W. *Energy Economics*, 2011, 33, (4), 665–673.

What is the best strategy to encourage research and development on new energy technologies in a market economy? What steps can ensure a rapid and efficient transition to an economy that has much lower net carbon emissions? This paper shows that, under limited conditions, a necessary and sufficient condition for an appropriate innovational environment is a universal, credible, and durable price on carbon emissions. Such a price would balance the marginal damages from carbon emissions against the marginal costs of abating emissions; it should not contain a correction factor for inducing technological change. This result, which the paper calls 'price fundamentalism', applies principally to the market-oriented part of research and innovation. It is subject to qualifications regarding the efficacy of intellectual property protection and the proper level of carbon prices, and it applies primarily to market sectors. The role of appropriate prices on emissions is a central part of public policies to encourage technologies to combat global warming.

12/00997 Development of a multicriteria tool for optimizing the renovation of buildings

Chantrelle, F. P. *et al. Applied Energy*, 2011, 88, (4), 1386–1394.

The renovation of a building involves not just the fulfilment of functional requirements, but also considerations such as energy consumption, investment costs, environmental impact and wellbeing. As things stand, new design methods and tools are needed, and the aim of the research presented in this article was to develop a multicriteria tool, MultiOpt, for the optimization of renovation operations, with an emphasis on building envelopes, heating and cooling loads and control strategies. MultiOpt is based on existing assessment software and methods: it uses a genetic algorithm (NSGA-II) coupled to TRNSYS, and economic and environmental databases. This article illustrates its utilization in the renovation of a school in the southern French city of Nice which was representative of France's building stock. The study started with the monocriterion optimization of energy consumption, cost, thermal comfort, and life-cycle environmental impact. It then moved onto multicriteria optimizations. The monocriterion analyses focused on the building's characteristics and performance; the multi-criteria analyses were concerned with the interactions between the different objectives, and with identifying their convergences and divergences. The results demonstrated that MultiOpt can be used to compare different combinations of options and constraints, thus constituting a basis for operational decision-making.

12/00998 Energy inputs and crop yield relationship in potato production in Hamadan province of Iran

Hamedani, S. R. *et al. Energy*, 2011, 36, (5), 2367–2371.

The aim of this study was to determine energy consumption and the relationship between energy input and yield for potato production in Kaboud Rahang region of Hamadan state. The data used in this study are collected by questionnaire. The results revealed that nitrogen fertilizer (39%), diesel (21%), seed (14.9%), water (7.5%) and manure (6.4%) consumed the bulk of energy. In the surveyed farms, average yield and energy consumption were calculated as around 28613.7 kg/ha, 92296.3 MJ/ha, respectively. The results also showed that energy ratio, specific energy and energy productivity were 1.1, 3.2 MJ/kg and 0.3 kg/MJ, respectively. An econometric model was developed to estimate the impact of energy inputs on yield by using parametric methods. For this purpose, potato yield, an endogenous variable was assumed to be a function of energy inputs: fertilizer manure, chemical, machinery, human, water for irrigation, diesel and seed. The empirical results indicated that variables: fertilizer, chemical, seed and human were found statistically significant and contributed to yield. Among statistically significant exogenous variables, seed, water for irrigation, chemical, human and fertilizer were ranked in terms of elasticities.

12/00999 Estimating vehicle emissions from road transport, case study: Dublin City

Achour, H. *et al. Applied Energy*, 2011, 88, (5), 1957–1964.

Air pollution is becoming a very important issue for the transportation sector, particularly car emissions in urban areas, and there is much interest in evaluating the actual level of emissions. In this paper, a case study of a standard driving cycle in the urban area of Dublin is presented. On-road, speed-time data was extracted by an on-board diagnostic tool, and saved into a data acquisition package. First, the driving cycle was established for the urban area of the city; one car travelling different routes has been employed to implement this research and some representative results have been achieved. The second part of the project was to estimate the emissions from the same car using the driving cycle obtained and compare the results with those obtained by a gas analyser attached to the car simultaneously in order to validate the methodology used in this paper. A representative driving cycle reflecting the real-world driving conditions is proposed and estimated vehicle emissions were compared with measured results. The method is easy to follow and the results are in a good fit to the estimated values.

12/01000 Experimental study on wave transmission coefficient, mooring lines and module connector forces with different designs of floating breakwaters

Peña, E. *et al. Ocean Engineering*, 2011, 38, (10), 1150–1160.

This paper presents the results and conclusions obtained from the physical model tests carried out with four different designs of floating breakwaters. Changes from a basic design have been introduced in order to evaluate the improvement in the efficiency as a coastal

protection structure. Incident and transmitted waves have been measured, as well as the efforts in the mooring lines and module connectors. It has been found that the width of the pontoons is one of the key design parameters, while small modifications in the floating breakwater's cross-section shape are less determinant in its hydrodynamic behaviour and in mechanical loads in the discussed ranges. Two- and three-dimensional tests were conducted, observing the great influence that the wave obliquity has in the module connector forces.

12/01001 How to select appropriate measures for reductions in negative environmental impact? Testing a screening method on a regional energy system

Dzene, I. *et al*. *Energy*, 2011, 36, (4), 1878–1883.
The aim of this study is to develop a method that allows selecting appropriate measures for reductions in negative environmental impacts on a regional energy system. In this paper a sophisticated screening method based on theoretical and practical basics of decision-making is proposed. The proposed method is applied and tested on the energy system of a typical rural middle-sized region in Latvia. The starting point for energy system analysis was evaluation of demand-side management options but later authors chose to include also primary energy to evaluate the whole regional energy system. The proposed method foresees different aspects: not only technical and economical possibilities, but also political and social factors that are very important in the decision-making process are taken into account.

12/01002 Impact of altitude on fuel consumption of a gasoline passenger car

Zervas, E. *Fuel*, 2011, 90, (6), 2340–2342.
Engines of new passenger cars are tuned at the sea level. However, in several countries, a significant part of the engine operation is performed at higher altitudes than that of the sea level. The different air density can have a significant impact on fuel consumption. In the case of gasoline engines, the higher altitude theoretically leads to lower fuel consumption due to lower throttle frictions due to the wider throttle opening. From the other side, as the air is less dense at higher altitudes, the vehicle aerodynamic is changed and this also leads to lower fuel consumption. This work studies, on three regulated driving cycles, the impact of high altitude on the fuel consumption of a gasoline passenger car. The impact of changed vehicle aerodynamics of higher altitudes, through the change of deceleration times, on fuel consumption is also analysed.

12/01003 Investigating the effectiveness of environmental assessment of land use change: a comparative study of the approaches taken to perennial biomass crop planting in São Paulo and England

Gallardo, A. L. C. F. and Bond, A. *Biomass and Bioenergy*, 2011, 35, (5), 2285–2297.
There is a move towards large-scale planting of perennial bioenergy crops in many countries to help reduce greenhouse gas emissions, while still meeting energy demand. However, the implications of such wholesale land-use change have yet to be fully understood which raises some concerns over the strategy. This paper identifies, through literature review, that significant social, economic and environmental impacts might be expected from land use change in two different parts of the world, São Paulo, Brazil, where sugarcane is the predominant perennial biomass crop, and England where *Miscanthus* and short rotation coppice are likely to predominate. In order to examine the extent to which these impacts can be addressed in decision-making, the paper develops a framework for testing the effectiveness of environmental assessment practice in these two regions, and applies it to both. The conclusion is that, whilst tools which can address sustainability impacts in decision-making exist, the legal framework in England precludes their application for the majority of land-use change, and in Brazil there is incomplete consideration of social and economic impacts at the strategic level.

12/01004 Land application of organic waste – effects on the soil ecosystem

Odlare, M. *et al*. *Applied Energy*, 2011, 88, (6), 2210–2218.
Growing populations and the increasing use of existing resources has led to growth in organic waste emissions. Therefore, a sustainable approach to managing this waste has become a major concern in densely populated areas. Biological treatment is an efficient method for reducing the amount of organic waste, and for producing energy. A large number of biogas plants and compost facilities that use organic waste as a substrate for electricity and fuel production are being built around the world. The biological treatment process in these plants produces large amounts of organic waste, and there is therefore a growing need to find a sustainable use for this material. Organic waste, such as biogas residues and compost can be a valuable fertilizer for agricultural soils. They can serve as a source of plant nutrients and can also improve soil structure and water holding capacity. However, as organic residues are known to contain both heavy metals and organic contaminants there is a need for long term field experiments to ensure that soil and plant quality is maintained. In order to investigate the potential risks and benefits of using organic waste in agriculture, an 8 year field experiment was established in central Sweden. Under realistic conditions, compost and biogas residues from source-separated household waste were compared with traditional mineral fertilizer. The authors examined crop yield and soil chemical and microbiological properties. The main conclusion from the field experiment was that biogas residues resulted in crop yields almost as high as the mineral fertilizer NPS. In addition, several important soil microbiological properties, such as substrate induced respiration, potential ammonium oxidation and nitrogen mineralization were improved after application of both biogas residues and compost. Moreover, no negative effects could be detected from using either of the organic wastes. In particular the genetic structure of the soil bacterial community appeared to resist changes caused by addition of organic waste.

12/01005 Measuring the social rate of return to R&D in coal, petroleum and nuclear manufacturing: a study of the OECD countries

Corderi, D. and Lin, C.-Y. C. *Energy Policy*, 2011, 39, (5), 2780–2785.
This paper estimates the social rate of return to research and development (R&D) in the energy manufacturing industry. The model tries to quantify the positive contribution that lagged R&D has on total factor productivity growth in the manufacturing of coal, petroleum products and nuclear fuel for a number of OECD countries. Using a panel of data from the OECD STAN database results can be obtain that suggest that R&D has a positive and significant rate of return that varies for each country.

12/01006 Multiple regression analysis of hydrogen sulphide poisoning in molten carbonate fuel cells used for waste-to-energy conversions

Zaza, F. *et al*. *International Journal of Hydrogen Energy*, 2011, 36, (13), 8119–8125.
Bioenergy addresses three important social concerns: security of energy supply, mitigation of greenhouse gas emissions and development of agriculture. Bioenergy is the energy generated by either direct or indirect combustion of biomass, which is non-fossil organic material of both vegetable and animal origins. Different technologies are currently available for bioenergy production, but fuel cells are one of the most interesting devices because of their environmental benefits and their high efficiency. In particular, molten carbonate fuel cells are suitable devices for waste-to-energy conversion because of their ability to be fed with biogas, which is biomass-derived gas rich in methane and carbon dioxide. Indeed, methane can be internally reformed to hydrogen, carbon dioxide is a safe diluent preventing electrolyte loss, and carbon monoxide acts both as a hydrogen supplier and as an actual fuel. Unfortunately, biogas impurities, such as sulfur, halogen and nitrogen compounds, cause adverse effects on cell performances. The most dangerous impurities are sulfur compounds, among whom hydrogen sulfide is the predominant and the most harmful chemicals. It reacts with nickel-based anode to form nickel sulfides, that block catalytic sites, slowing hydrogen oxidation down, and change the anode wettability in molten carbonates, compromising the optimal electrolyte distribution within cell components. Poisoning mechanism of hydrogen sulfide depends on operating conditions such as current density, anodic gas composition, temperature and pressure. The aim of this work is to study hydrogen sulfide effects on MCFCs by means of multiple regression analysis. The mathematical approach gives us tools to define the main sulfur poisoning mechanism under MCFC operating conditions, quantify the effects of the main parameters affecting poison actions, such as current density, hydrogen and hydrogen sulfide, and identify their mutual interactions. Also it is possible to formulate a multivariate model to predict sulfur poisoning.

12/01007 Property risk assessment for power plants: methodology, validation and application

Orme, G. J. and Venturini, M. *Energy*, 2011, 36, (5), 3189–3203.
In this paper, a procedure for risk assessment, which makes use of two risk indices (PML – probable maximum loss and MFL – maximum foreseeable loss) is applied to power plants to evaluate potential economic losses due to risk exposure for two different loss scenarios (probable and worst-case). First, the procedure is presented in order to provide a prediction of probable and maximum loss as a function of power output. Second, the economic loss predicted through the risk assessment procedure is compared to real power plant loss values, taken from published data, to validate the methodology against field data. Finally, the procedure is applied to some combined-cycle power plants by also including the contribution of business interruption losses. In this manner, the most common sources of loss are identified. A sample analysis for risk/benefit evaluation is also carried out to estimate whether the adoption of risk assessment procedures allows an actual profit for plant owners. Customer feedback is also discussed.

The results presented in this paper allow a practical and easy-to-use rule of thumb for loss estimation and a guideline for plant owners to evaluate the impact of risk assessment procedures on operational costs.

12/01008 Public acceptance for environmental taxes: self-interest, environmental and distributional concerns
Kallbekken, S. and Sælen, H. *Energy Policy*, 2011, 39, (5), 2966–2973.
While strongly recommended by economists, it has often been politically difficult to impose taxes on externalities. There is a substantial literature on public attitudes towards environmental taxes. There has, however, been few comprehensive attempts to understand attitudes towards environmental taxes. The main research question in this paper is which factors influence support for fuel taxation. The authors propose a model of attitudes towards fuel taxation, and test this model as well as more specific hypotheses, using data from a representative survey of the adult Norwegian population. The results suggest that support for fuel taxation is best predicted by beliefs about environmental consequences, followed by beliefs about consequences to others. Beliefs about consequences to self (self-interest) is the factor that explains the least variation in support for fuel taxation. The academically interesting result that support cannot be well explained without capturing a broad range of motivational factors is also highly policy relevant. It implies that there is no magic formula for increasing public support for environmental taxes. There are, however, some issues which can be addressed: trust in how well the government spends the revenue, and the perception that taxation does very little to change behaviour and thus to reduce environmental problems.

12/01009 Technologies, preferences, and policies for a sustainable use of natural resources
Bretschger, L. and Smulders, S. *Resource and Energy Economics*, 2011, 33, (4), 881–892.
This study discusses eight contributions that combine the topics of sustainable natural resource use and economic dynamics. In the first part the authors consider enhanced oil recovery (EOR), carbon capture and storage (CCS), as well as innovations allowing for energy-efficiency improvements and renewable energy cost reductions. They discuss how to include these technologies and innovations in CGE models, how each of them has different effects on the timing of emissions and abatement and on total emissions, and how (first-best as well as second-best) complementary policies (in particular, emission taxes and innovation subsidies) differ across these technologies. In the second part the authors compare differences in intergenerational preferences towards resource conservation – altruistic preferences and concern for social status from relative consumption -and also found sharply contrasting effects across the alternative assumptions.

12/01010 The future of the European emission trading system and the clean development mechanism in a post-Kyoto world
Klepper, G. *Energy Economics*, 2011, 33, (4), 687–698.
This paper discusses developments in the markets for CO_2 emissions rights since the Kyoto Protocol was signed. The different emissions trading schemes, dominated by the emission trading system of the European Union and the clean development mechanism, are surveyed. These schemes will need to be incorporated into any post-Kyoto multilateral agreement. Drawing on a simple model, the paper analyses the incentives that developing and developed countries face for continuing or transforming the clean development mechanism in the light of future agreements for a worldwide emissions control program.

12/01011 Visualizing energy consumption activities as a tool for making everyday life more sustainable
Ellegård, K. and Palm, J. *Applied Energy*, 2011, 88, (5), 1920–1926.
The need to analyse and understand energy consumption in relation to households' activity patterns is vital for developing policy means that contribute to an energy efficient life and what people would deem as a 'good' everyday life. To do this more information is needed about how energy use is a part of everyday life; this paper contributes to that objective. The study uses the time-geographic diary approach together with interviews to analyse everyday life as a totality. Household members' time diaries provide information to analyse and learn about when, where, and what energy-related activities occur in a household context and by whom (and in what social context) they are performed. Here, the authors discuss the importance of relating information and feedback to households' everyday activities, in order to make it relevant to households. Through this method activity patterns in a household during a given period are established. The method is also useful to households as a reflective tool when discussing families' daily lives in relation to energy consumption. The method gives direct feedback to households and the information is relevant since it emanates from their own reported activities.

12/01012 Water quality impact assessment of large-scale biofuel crops expansion in agricultural regions of Michigan
Love, B. J. *et al. Biomass and Bioenergy*, 2011, 35, (5), 2200–2216.
In this study, the soil and water assessment tool (SWAT) was used to predict the possible long-term environmental implications, specifically water quality, due to large-scale bioenergy cropping system expansion based on four land-use scenarios and 15 bioenergy crop rotations for four watersheds, totalling 244 model simulations. The study area consists of four watersheds totalling 53,358 km^2 located in Michigan. The results suggest that perennial grass species are the most suitable for large-scale implementation, whereas traditional intensive row crops should be implemented with caution on such a broad scale. Row crops also had the highest increases of high priority areas for sediment, nitrogen, and phosphorus. Based on the data from this study, it is not recommended that marginal land be converted to any bioenergy rotation in areas with pre-existing high nitrogen levels. Statistical analyses demonstrate that perennial grass species significantly reduce sediment on all lands except marginal lands. With the exception of row crops cultivated on marginal lands and all agricultural land, the majority of bioenergy crops significantly reduce total phosphorus loads.

CO_2, NO_x, SO_2 and particulate emissions

12/01013 A projection for global CO_2 emissions from the industrial sector through 2030 based on activity level and technology changes
Akashi, C. *et al. Energy*, 2011, 36, (4), 1855–1867.
This study simulates global CO_2 emissions and their reduction potentials in the industrial sector up to the year 2030. Future industrial CO_2 emissions depend on changes in both technology and industrial activity. However, earlier bottom-up analyses mainly focused on technology change. Here the authors estimate changes in both technology and industrial activity. They developed a three-part simulation system. The first part is a macro-economic model that simulates macro-economic indicators, such as GDP and value added by sector. The second part consists of industrial production models that simulate future steel and cement production. The third part is a bottom-up type technology model that estimates future CO_2 emissions. Assuming no changes in technology since 2005, it was estimated that global CO_2 emissions in 2030 increase by 15 $GtCO_2$ from 2005 level. This increase is due to growth in industrial production. Introducing technological reduction options within 100 US$/$tCO_2$ provides a reduction potential of 5.3 $GtCO_2$ compared to the case of no technology changes. As a result, even with large technological reduction potential, global industrial CO_2 emissions in 2030 are estimated to be higher as compared to 2005 level because of growth of industrial production.

12/01014 Allocation of sulphur dioxide allowance – an analysis based on a survey of power plants in Fujian province in China
Lin, B. *et al. Energy*, 2011, 36, (5), 3120–3129.
The rapid growth of the Chinese economy has led to an acceleration of electricity demand, which has enjoyed an annual growth rate above 10% during the past 20 years. However, China's coal-based resource endowment heavily influences its energy structure in the long term, which will result in more serious environment deterioration, and consequently threaten the sustainable development of China. As an effective pollution control policy that can reduce pollution at the lowest cost, emissions trading is one of the environmental policies that elicit the international interest. In addition, it is also an important economic tool to control sulfur dioxide (SO_2) emissions, which has been proved successful in meeting prescribed environmental goals at lower cost than traditional regulate approaches, and now is being pilot-test in China. Since the power industry accounts for more than half of China's total coal consumption, emissions control in the power industry is the key to realize the emissions reduction objectives claimed in the 'Eleventh Five-year Plan'. Based on an investigation of 14 power plants in Fujian province, this article compares four different allocation methods for sulfur dioxide allowance. The results indicate that the emissions performance method and production value method are the most suitable methods for Fujian power plants.

12/01015 Comparison of particle emissions from an engine operating on biodiesel and petroleum diesel
Zhang, J. *et al. Fuel*, 2011, 90, (6), 2089–2097.
Biodiesel is an alternative fuel with growing usage in the transportation sector. To compare biodiesel and petroleum diesel effects on particle emissions, engine dynamometer tests were performed on a Euro II engine with three test fuels: petroleum diesel (D), biodiesel made from

soy bean oil (BS) and biodiesel made from waste cooking oil (BW). $PM_{2.5}$ samples were collected on Teflon and quartz filters with a Model 130 High-Flow Impactor (MSP Corp). Organic (OC) and elemental (EC) carbon fractions of $PM_{2.5}$ were quantified by a thermal-optical reflectance analysis method and particle size distributions were measured with an electrical low pressure impactor (ELPI). In addition, the gaseous pollutants were measured by an AMA4000 (AVL Corp). The biodiesels were found to produce 19–37% less and 23–133% more $PM_{2.5}$ compared to the petroleum diesel at higher and lower engine loads respectively. On the basis of the carbon analysis results, the biodiesel application increased the $PM_{2.5}$ OC emissions by 12–190% and decreased the $PM_{2.5}$ EC emissions by 53–80%, depending on the fuel and engine operation parameters. Therefore OC/EC was increased by three to eight times with biodiesel application. The geometrical mean diameter of particles from biodiesels and petroleum diesel had consistent trends with load and speed transition. In all the conditions, there is a shift of the particles towards smaller geometric mean diameter for the biodiesel made from waste oil.

12/01016 CO_2 and pollutant emissions from passenger cars in China

Wang, H. *et al. Energy Policy*, 2011, 39, (5), 3005–3011.

In this paper, CO_2 and pollutant emissions of PCs in China from 2000 to 2005 were calculated based on a literature review and measured data. The future trends of PC emissions were also projected under three scenarios to explore the reduction potential of possible policy measures. Estimated baseline emissions of CO, HC, NO_x, PM_{10} and CO_2 were respectively 3.16×10^6, 5.14×10^5, 3.56×10^5, 0.83×10^4 and 9.14×10^7 tons for China's PCs in 2005 with an uneven distribution among provinces. Under a no improvement (NI) scenario, PC emissions of CO, HC, NO_x, PM_{10} and CO_2 in 2020 are respectively estimated to be 4.5, 2.5, 2.5, 7.9 and 8.0 times that of 2005. However, emissions other than CO_2 from PCs are estimated to decrease nearly 70% by 2020 compared to NI scenario mainly due to technological improvement linked to the vehicle emissions standards under a recent policy (RP) scenario. Fuel economy (FE) enhancement and the penetration of advanced propulsion/fuel systems could be co-benefit measures to control CO_2 and pollutant emissions for the mid and long terms. Significant variations were found in PC emission inventories between different studies primarily due to uncertainties in activity levels and/or emission factors (EF).

12/01017 CO_2 emissions of Turkish manufacturing industry: a decomposition analysis

Akbostanci, E. *et al. Applied Energy*, 2011, 88, (6), 2273–2278.

In this study, CO_2 emissions of Turkish manufacturing industry are calculated by using the fuel consumption data at ISIC revision 2, four-digit level. Study covers 57 industries, for the 1995–2001 period. Log mean divisia index (LMDI) method is used to decompose the changes in the CO_2 emissions of manufacturing industry into five components; changes in activity, activity structure, sectoral energy intensity, sectoral energy mix and emission factors. Mainly, it is found that changes in total industrial activity and energy intensity are the primary factors determining the changes in CO_2 emissions during the study period. It is also indicated that among the fuels used, coal is the main determining factor and among the sectors, 3710 (iron and steel basic industries) is the dirtiest sector dominating the industrial CO_2 emissions in the Turkish manufacturing industry.

12/01018 Scaling up carbon dioxide capture and storage: from megatons to gigatons

Herzog, H. J. *Energy Economics*, 2011, 33, (4), 597–604.

Carbon dioxide capture and storage (CCS) is the only technology that can reduce CO_2 emissions substantially while allowing fossil fuels to meet the world's pressing energy needs. Even though the technological components of CCS – separation of CO_2 from emissions, transport, and secure storage – are all in use somewhere in the economy, they do not currently function together in the manner required for large-scale CO_2 reduction. The challenge for CCS to be considered commercial is to integrate and scale up these components. Significant challenges remain in growing CCS from the megaton level where it is today to the gigaton level where it needs to be to help mitigate global climate change. These challenges, none of which are showstoppers, include lowering costs, developing needed infrastructure, reducing subsurface uncertainty, and addressing legal and regulatory issues. Progress will require a series of demonstration projects worldwide, an economically viable policy framework, and the evolution of a business model.

Life cycle analysis

12/01019 Cofiring versus biomass-fired power plants: GHG (greenhouse gases) emissions savings comparison by means of LCA (life cycle assessment) methodology

Sebastián, F. *et al. Energy*, 2011, 36, (4), 2029–2037.

One way of producing nearly CO_2 free electricity is by using biomass as a combustible. In many cases, removal of CO_2 in biomass grown is almost the same as the emissions for the bioelectricity production at the power plant. For this reason, bioelectricity is generally considered CO_2 neutral. For large-scale biomass electricity generation two alternatives can be considered: biomass-only fired power plants, or cofiring in an existing coal power plant. Among other factors, two important aspects should be analysed in order to choose between the two options. Firstly, which is the most appealing alternative if their greenhouse gases (GHG) emissions savings are taken into account. Secondly, which biomass resource is the best, if the highest impact reduction is sought. In order to quantify all the GHG emissions related to each system, a life cycle assessment methodology has been performed and all the processes involved in each alternative have been assessed in a cradle-to-grave manner. Sensitivity analyses of the most dominant parameters affecting GHG emissions, and comparisons between the obtained results, have also been carried out.

12/01020 Comparative life cycle environmental assessment of CCS technologies

Singh, B. *et al. International Journal of Greenhouse Gas Control*, 2011, 5, (4), 911–921.

Hybrid life cycle assessment is used to assess and compare the life cycle environmental impacts of electricity generation from coal and natural gas with various carbon capture and storage (CCS) technologies consisting of post-combustion, pre-combustion or oxyfuel capture; pipeline CO_2 transport and geological storage. The systems with a capture efficiency of 85–96% decrease net greenhouse gas emission by 64–78% depending on the technology used. Calculation of other life cycle impacts shows significant trade-offs with fresh-water eutrophication and toxicity potentials. Human toxicity impact increases by 40–75%, terrestrial ecotoxicity by 60–120%, and freshwater eutrophication by 60–200% for the different technologies. There is a two- to four-fold increase in freshwater ecotoxicity potential in the post-combustion approach. The increase in toxicity for pre-combustion systems is 40–80% for the coal and 50–90% for the gas power plant. The increase in impacts for the oxyfuel approach mainly depends on energy demand for the air separation unit, giving an increase in various toxicity potentials of 35–70% for coal and 60–105% for natural gas system. Most of the increase in impacts with CCS systems is due to the energy penalty and the infrastructure development chain.

12/01021 Consequential life cycle assessment of the environmental impacts of an increased rapemethylester (RME) production in Switzerland

Reinhard, J. and Zah, R. *Biomass and Bioenergy*, 2011, 35, (6), 2361–2373.

Arable land is a constrained production factor – particular in Switzerland. Merely 45% of the consumed crops are produced domestically. Hence, the additional cultivation of rape for producing methyl ester is assumed to substitute crops used for food production. Consequently, Switzerland has to face the decision either to use the arable land for food production and import fuels or to produce fuel from rape and import the displaced food. Using consequential life cycle assessment (CLCA), the environmental consequences have been assessed if rape for energetic utilization substitutes rape used as edible oil or barley used as animal fodder. The study shows, that displacing food production by RME production in Switzerland can reduce total GHG emissions, when GHG-intense soy meal from Brazil is substituted by rape and sunflower meal, which is a co-product of the vegetable oil production. On the other hand, an increased production of vegetable oils increases various other environmental factors, because agricultural production of edible oil is associated with higher environmental impacts than the production and use of fossil fuels. In summary, the environmental impacts of an increased RME production in Switzerland rather depend on the environmental scores of the marginal replacement products on the world market, than on local production factors.

12/01022 Environmental assessment of grid connected photovoltaic plants with 2-axis tracking versus fixed modules systems

Bayod-Rújula, Å. A. *et al. Energy*, 2011, 36, (5), 3148–3158.

The use of two-axis tracking systems has been widely implemented because of the higher rates in energy production that these systems can achieve. However, the reduction of the PV modules cost makes the economic advantage of these tracking systems not so evident and this

has aroused the interest of analysing them from other points of view such as efficiency or energy performance and environmental impact. Most of the existing LCA studies related to photovoltaic systems are focused in the comparison of the different technologies used for cell production; some reports include also the module assembly, but there is little information regarding the environmental impact caused by the complete solar photovoltaic plant. In this paper, a life cycle analysis of two types of installations (with and without solar tracking) in different geographic locations is presented. The methodology, based on recognized international standards, provides the best framework for assessing the most relevant factors causing the environmental impacts and gives relevant information for further improvements. The results also allow the comparison of different solutions and the calculation of the energy and environmental payback time of both configurations.

12/01023 Incorporating life cycle assessments into building project decision-making: an energy consumption and CO_2 emission perspective

Tsai, W.-H. *et al. Energy*, 2011, 36, (5), 3022–3029.

In the past two decades, the globalization of financial markets and multinational trade has intensified internationally, and become increasingly competitive. In the construction industry, critical changes are initiated to reduce operating costs for achieving sustainable operation. Conventional cost pricing for building projects no longer apply as energy shortage and environmental pollution are new challenges faced by construction companies. Many countries have attempted to solve the CO_2 emission problems by levying a carbon tax, which leads to a higher cost for construction companies. Therefore, this study aims to adopt life cycle assessment (LCA) in order to assess CO_2 emission costs and apply a mathematical programming approach to allocate limited resources to maximize profits for construction companies.

12/01024 Life cycle analysis and cost of a molten carbonate fuel cell prototype

Monaco, A. and Di Matteo, U. *International Journal of Hydrogen Energy*, 2011, 36, (13), 8103–8111.

Life cycle analysis (LCA) is a method enabling the performance of a complete study on the environmental impacts of the product, taking into consideration all its life cycle ('from the cradle to the tomb' or, better 'from the cradle to the cradle' when also the maximum recycling/reusing of the materials is provided. There are many procedures to perform an LCA of the consumers' products. In particular, the SUMMA method (sustainability multi-criteria multi-scale assessment) allows obtaining a number of indices of efficiency and environmental sustainability which make the LCA assessment much more complete and significant. LCA often represents the basis for an additional assessment of industrial products and processes, the LCC (life cycle costing) which, allowing the association of economic variables to any phase of the life cycle, represents a useful tool for financial planning and management. The case study analysed in the present work concerns an LCA analysis, using the SUMMA method and the LCC of one small-sized molten carbonate fuel cell (2.5 kW). For sake of completeness of the results, the methods Ecoindicator99 and Impact2002+ were used in the analysis, as implemented in the used calculation software, the SimaPro 7.1 (PRè Consultants). From the registered results, it emerges that the environmental energy sustainability of the analysed element enables its widespread and in-depth employment in the phase subsequent to the optimization of the connected economic frame; the scenarios opened by the present work envisage great margins of improvements of said aspects in the future experiments.

12/01025 Life cycle analysis of processes for hydrogen production

Smitkova, M. *et al. International Journal of Hydrogen Energy*, 2011, 36, (13), 7844–7851.

One of the most remarkable methods for large-scale hydrogen production is thermochemical water decomposition using heat energy from nuclear, solar and other sources. Detailed simulations of the two most promising water splitting thermochemical cycles (the Westinghouse cycle and the sulfur–iodine cycle) were performed in Aspen Plus code and obtained results were used for life cycle analysis. They were compared with two different processes for hydrogen production (coal gasification and coal pyrolysis). Some of the results obtained from LCA are also reported in the paper.

12/01026 Life cycle assessment in buildings: the ENSLIC simplified method and guidelines

Malmqvist, T. *et al. Energy*, 2011, 36, (4), 1900–1907.

Life cycle assessment (LCA) is currently used to a very limited extent in the building sector, for several reasons. Firstly, making an LCA evaluation of a building demands a specific tool to handle the large dataset needed and this tool has to be adaptable to the different decisions taken throughout the life cycle of the building. Such tools have been developed in a few countries, but they are exceptions. However, useful experience has been gained in these countries, providing a valuable source of data for developing guidelines for application in other countries. Since the results of a building LCA may contain complex information, the great challenge is to devise efficient ways for communication of the results to users and clients. The simplified methodology presented in this paper adopt a systematic approach guiding the user through the life cycle process and clarifying key issues that usually cause difficulty, e.g. choice of assessment tool, definition of system boundaries, options for simplifying the process, etc. The guidelines were developed within the framework of the ENSLIC Building Project, which was co-funded by the European Commission Intelligent Energy for Europe Programme and by nine European organizations that included more than 15 LCA experts and architects.

12/01027 Life cycle assessment of biohydrogen production in photosynthetic processes

Romagnoli, F. *et al. International Journal of Hydrogen Energy*, 2011, 36, (13), 7866–7871.

The outcomes of biohydrogen from photosynthesis processes are still small, however different development methods and laboratory studies are carried out to increase the production yield and meanwhile optimize the process to lessen the negative impact on the environment and climate change. The life cycle assessment (LCA) gives the possibility to compare different biohydrogen production approaches using different photosynthesis methods and, at the same time, identify the environmental 'hot spots' of the whole process. Inventory analysis and the results of different researchers in this field allow to find values of selected ecoindicators in order to evaluate the biohydrogen production efficiency with the selection of the best initial data for LCA. These ecoindicators weigh the resources needed for biohydrogen production whole system. This paper presents the first aspects for the implementation of a LCA.

12/01028 Life cycle assessment of natural gas combined cycle power plant with post-combustion carbon capture, transport and storage

Singh, B. *et al. International Journal of Greenhouse Gas Control*, 2011, 5, (3), 457–466.

Hybrid life cycle assessment has been used to assess the environmental impacts of natural gas combined cycle (NGCC) electricity generation with carbon dioxide capture and storage (CCS). The CCS chain modelled in this study consists of carbon dioxide (CO_2) capture from flue gas using monoethanolamine (MEA), pipeline transport and storage in a saline aquifer. Results show that the sequestration of 90% CO_2 from the flue gas results in avoiding 70% of CO_2 emissions to the atmosphere per kWh and reduces global warming potential (GWP) by 64%. Calculation of other environmental impacts shows the trade-offs: an increase of 43% in acidification, 35% in eutrophication, and 120–170% in various toxicity impacts. Given the assumptions employed in this analysis, emissions of MEA and formaldehyde during capture process and generation of reclaimer wastes contributes to various toxicity potentials and cause many-fold increase in the on-site direct freshwater ecotoxicity and terrestrial ecotoxicity impacts. NO_x from fuel combustion is still the dominant contributor to most direct impacts, other than toxicity potentials and GWP. It is found that the direct emission of MEA contribute little to human toxicity (HT < 1%), however it makes 16% of terrestrial ecotoxicity impact. Hazardous reclaimer waste causes significant freshwater and marine ecotoxicity impacts. Most increases in impact are due to increased fuel requirements or increased investments and operating inputs. The reductions in GWP range from 58% to 68% for the worst-case to best-case CCS system. Acidification, eutrophication and toxicity potentials show an even large range of variation in the sensitivity analysis. Decreases in energy use and solvent degradation will significantly reduce the impact in all categories.

12/01029 Life cycle assessment of the offshore wind farm Alpha Ventus

Wagner, H.-J. *et al. Energy*, 2011, 36, (5), 2459–2464.

Due to better wind conditions at sea, offshore wind farms have the advantage of higher electricity production compared to onshore and inland wind farms. In contrast, a greater material input, leading to increased energy consumptions and emissions during the production phase, is required to build offshore wind farms. These contrary effects are investigated for the first German offshore wind farm Alpha Ventus in the North Sea. In a life cycle assessment its environmental influence is compared to that of Germany's electricity mix. In comparison to the mix, Alpha Ventus had better indicators in nearly every investigated impact category. One kilowatt-hour electricity, generated by the wind farm, was burdened with 0.137 kWh primary energy-equivalent and 32 g CO_2-equivalent, which represented only a small proportion of the accordant values for the mix. Furthermore, the offshore foundations as well as the submarine cable were the main energy intensive

components. The energetic and greenhouse gas payback period was less than a year. Therefore, offshore wind power, even in deep water, is compatible with the switch to sustainable electricity production relying on renewable energies. Additional research, taking backup power plants as well as increasingly required energy storage systems into account, will allow further calculation.

12/01030 Life cycle cost implications of energy efficiency measures in new residential buildings

Morrissey, J. and Horne, R. E. *Energy and Buildings*, 2011, 43, (4), 915–924.

The importance of the built environment from an environmental impact and energy use perspective is well established. High thermal efficiency of the constructed building envelope is a key strategy in the design and construction of buildings that limit use of active space conditioning systems. Australia's current housing stock is thermally poor and national energy performance standards are relatively weak when benchmarked against international best practice. A lack of data has impeded the policy debate and a significant gap in analysis remains a lack of empirical research into the life-cycle cost implications of increased building thermal efficiency, particularly for residential buildings. This paper applies an integrated thermal modelling, life cycle costing approach to an extensive sample of dominant house designs to investigate life cycle costs in a cool temperate climate, Melbourne, Victoria. Empirical analysis provides new insights into lifetime costs and environmental savings for volume housing design options and identifies sensitive factors. Results suggest that the most cost-effective building design is always more energy efficient than the current energy code requirements, for the full time-horizon considered. Findings have significant policy implications, particularly in view of present debates which frequently present higher energy efficiency standards as prohibitive from a costs perspective.

12/01031 Life cycle GHG emissions from Malaysian oil palm bioenergy development: the impact on transportation sector's energy security

Hassan, M. N. A. *et al. Energy Policy*, 2011, 39, (5), 2615–2625.

Malaysia's transportation sector accounts for 41% of the country's total energy use. The country is expected to become a net oil importer by the year 2011. To encourage renewable energy development and relieve the country's emerging oil dependence, in 2006 the government mandated blending 5% palm-oil biodiesel in petroleum diesel. Malaysia produced 16 million tonnes of palm oil in 2007, mainly for food use. This paper addresses maximizing bioenergy use from oil-palm to support Malaysia's energy initiative while minimizing greenhouse-gas emissions from land-use change. When converting primary and secondary forests to oil-palm plantations between 270–530 and 120–190 g CO_2-equivalent per MJ of biodiesel produced, respectively, is released. However, converting degraded lands results in the capture of between 23 and 85 g CO_2-equivalent per MJ of biodiesel produced. Using various combinations of land types, Malaysia could meet the 5% biodiesel target with a net greenhouse gas (GHG) savings of about 1.03 million tonnes (4.9% of the transportation sector's diesel emissions) when accounting for the emissions savings from the diesel fuel displaced. These findings are used to recommend policies for mitigating GHG emissions impacts from the growth of palm oil use in the transportation sector.

12/01032 Life cycle greenhouse gas emissions impacts of the adoption of the EU Directive on biofuels in Spain. Effect of the import of raw materials and land use changes

Lechon, Y. *et al. Biomass and Bioenergy*, 2011, 35, (6), 2374–2384.

The objective of this paper is to evaluate the greenhouse gas (GHG) emissions impacts of the use of different alternative biofuels in passenger vehicles in Spain in order to meet European Union (EU) biofuel goals. Different crop production alternatives are analysed, including the possible import of some raw materials. Availability of land for national production of the raw materials is analysed and indirect land use changes and associated GHG emissions are quantified. There are important differences in GHG emissions of biofuels depending on the raw material used and whether this is domestically produced or imported. Ethanol production using imported cereals and FAME production using domestic rapeseed have the highest GHG emissions per kilometre driven. Fatty acid methyl ester (FAME) production from sunflower has shown the lowest emissions. When taking into account the results of GHG emissions savings per hectare, these findings are somehow reversed. Production of ethanol and around 12% of FAME can be done domestically. The rest will need to be imported and will cause indirect land use change (ILUC). Therefore, ethanol production will not displace any land, whereas FAME production will displace some amounts of land. Calculated ILUC factors are 29%–34%. The additional GHG emissions due to these indirect land use changes are significant (67%–344% of life cycle GHG emissions). Standalone, the EU biofuel targets can have important benefits for Spain in terms of global warming emissions avoided. However, when considering the impact of land use change effects, these benefits are significantly reduced and can even be negative.

12/01033 Life-cycle assessment of a 100% solar fraction thermal supply to a European apartment building using water-based sensible heat storage

Simons, A. and Firth, S. K. *Energy and Buildings*, 2011, 43, (6), 1231–1240.

Providing 100% of a building's heating and hot water using a solar thermal system in a European climate has been shown to be both practically feasible and functionally successful for a new apartment building in Switzerland. The research conducted a life cycle assessment of the solar thermal system and compared the results with an air-source heat-pump, ground-source heat pump, natural gas furnace, oil furnace and a wood-pellet furnace. Using a range of lifetime scenarios it was found that the solar thermal system displays potentially significant advantages over all other systems in terms of reductions for purchased primary energy (from 84 to 93%) and reductions in greenhouse gas emissions (from 59 to 97%). However, due to the heavy industrial processes and the particular metals used in manufacturing, the solar thermal system was shown to have a higher demand for resources which, in relation to the natural gas system, can be by a factor of almost 38. Potential impacts on ecosystem quality were marginally worse than for the heat-pump and fossil fuel systems due to resource use impacts whilst potential human health impacts were similar to the heat pump systems but better than the fossil and biomass fuelled systems.

12/01034 Life-cycle greenhouse gas emissions and energy balances of sugarcane ethanol production in Mexico

García, C. A. *et al. Applied Energy*, 2011, 88, (6), 2088–2097.

The purpose of this work was to estimate GHG emissions and energy balances for the future expansion of sugarcane ethanol fuel production in Mexico with one current and four possible future modalities. The authors used the life cycle methodology that is recommended by the European Union's renewable energy directive (RED), which distinguished the following five system phases: direct land use change (LUC); crop production; biomass transport to industry; industrial processing; and ethanol transport to admixture plants. Key variables affecting total greenhouse gas emissions and fossil energy used in ethanol production were LUC emissions, crop fertilization rates, the proportion of sugarcane areas that are burned to facilitate harvest, fossil fuels used in the industrial phase, and the method for allocation of emissions to co-products. The lower emissions and higher energy ratios that were observed in the present Brazilian case were mainly due to the lesser amount of fertilizers applied, also were due to the shorter distance of sugarcane transport, and to the smaller proportion of sugarcane areas that were burned to facilitate manual harvest. The resulting modality with the lowest emissions of equivalent carbon dioxide (CO_{2e}) was ethanol produced from direct juice and generating surplus electricity with 36.8 $kgCO_{2e}/GJ_{ethanol}$. This was achieved using bagasse as the only fuel source to satisfy industrial phase needs for electricity and steam. Mexican emissions were higher than those calculated for Brazil (27.5 $kgCO_{2e}/GJ_{ethanol}$) among all modalities. The Mexican modality with the highest ratio of renewable/fossil energy was also ethanol from sugarcane juice generating surplus electricity with 4.8 $GJ_{ethanol}/GJ_{fossil}$.

12/01035 Lifetime optimization of a molten carbonate fuel cell power system coupled with hydrogen production

Nicolin, F. and Verda, V. *Energy*, 2011, 36, (4), 2235–2241.

In this paper, a biogas-fuelled energy system for combined production of electricity and hydrogen is considered. The system is based on a molten carbonate fuel cell stack integrated with a micro-gas turbine. Hydrogen is produced by a pressure swing absorption system. A multi-objective optimization is performed, considering the electrical efficiency and the unit cost of electricity as the objective functions. The system operation is affected by variations in fuel composition, ambient temperature and performance degradation of the components occurring during its lifetime. These effects are considered while defining the objective functions.

12/01036 Prospective life cycle carbon abatement for pyrolysis biochar systems in the UK

Hammond, J. *et al. Energy Policy*, 2011, 39, (5), 2646–2655.

Life cycle assessment (LCA) of slow pyrolysis biochar systems (PBS) in the UK for small-, medium- and large-scale process chains and 10 feedstocks was performed, assessing carbon abatement and electricity production. Pyrolysis biochar systems appear to offer greater carbon abatement than other bioenergy systems. Carbon abatement of 0.7–1.3 t CO_2 equivalent per oven dry tonne of feedstock processed was found. In terms of delivered energy, medium to large scale PBS abates 1.4–1.9 t CO_2e/MWh, which compares to average carbon emissions of 0.05–0.30 t CO_2e/MWh for other bioenergy systems. The largest contribution to PBS carbon abatement is from the feedstock carbon

stabilized in biochar (40–50%), followed by the less certain indirect effects of biochar in the soil (25–40%) – mainly due to increase in soil organic carbon levels. Change in soil organic carbon levels was found to be a key sensitivity. Electricity production off-setting emissions from fossil fuels accounted for 10–25% of carbon abatement. The LCA suggests that provided 43% of the carbon in the biochar remains stable, PBS will out-perform direct combustion of biomass at 33% efficiency in terms of carbon abatement, even if there is no beneficial effect on soil organic carbon levels from biochar application.

12/01037 Soil organic carbon changes in the cultivation of energy crops: implications for GHG balances and soil quality for use in LCA
Brandão, M. *et al. Biomass and Bioenergy*, 2011, 35, (6), 2323–2336.
The environmental impact of different land-use systems for energy, up to the farm or forest 'gate', has been quantified with life cycle assessment (LCA). Four representative crops are considered: oilseed rape (OSR), *Miscanthus*, short-rotation coppice (SRC) willow and forest residues. The focus of the LCA is on changes in soil organic carbon (SOC) but energy use, emissions of greenhouse gases (GHGs), acidification and eutrophication are also considered. In addition to providing an indicator of soil quality, changes in SOC are shown to have a dominant effect on total GHG emissions. *Miscanthus* is the best land-use option for GHG emissions and soil quality as it sequesters carbon at a higher rate than the other crops, but this has to be weighed against other environmental impacts where *Miscanthus* performs worse, such as acidification and eutrophication. OSR shows the worst performance across all categories. Because forest residues are treated as a by-product, their environmental impacts are small in all categories. The analysis highlights the need for detailed site-specific modelling of SOC changes, and for consequential LCAs of the whole fuel cycle including transport and use.

12/01038 The energy consumption and environmental impacts of SCR technology in China
Liang, Z. *et al. Applied Energy*, 2011, 88, (4), 1120–1129.
Energy and environment are drawing greater attention today, particularly with the rapid development of the economy and increase consumption of energy in China. At present, coal-fired power plants are mainly responsible for atmospheric air pollution. The selective catalytic reduction (SCR) technology is a highly effective method for NO_x control. The present study identified and quantified the energy consumption and the environmental impacts of SCR system throughout the whole life cycle, including production and transportation of manufacturing materials, installation and operation of SCR technology. The analysis was conducted with the utilization of life cycle assessment (LCA) methodology which provided a quantitative basis for assessing potential improvements in the environmental performance of the system. The functional unit of the study was 5454 t NO_x emission from an existing Chinese pulverized coal power plant for 1 year. The current study compared life cycle emissions from two types of de-NO_x technologies, namely the SCR technology and the selective non-catalytic reduction (SNCR) technology, and the case that NO_x was emitted into atmosphere directly. The results showed that the environmental impact loading resulting from SCR technology (66,810 PET_{2000}) was smaller than that of flue gas emitted into atmosphere directly (164,121 PET_{2000}) and SNCR technology (105,225 PET_{2000}). More importantly, the SCR technology is much more effective at the elimination of acidification and nutrient enrichment than SNCR technology and the case that NO_x emitted into atmosphere directly. This SCR technology is more friendly to the environment, and can play an important role in NO_x control for coal-fired power plants as well as industrial boilers.

16 ENERGY

Supplies, policy, economics, forecasts

12/01039 A conceptual framework for estimating the climate impacts of land-use change due to energy crop programs
Delucchi, M. *Biomass and Bioenergy*, 2011, 35, (6), 2337–2360.
This study discusses the general conceptual issues in the estimation of the impacts of CO_2 emissions from soils and biomass, over time, as a result of land-use change (LUC) due to increased demand for energy crops. The effect of LUC on climate depends generally on the magnitude and timing of changes in soil and plant carbon, and in particular on the timing and extent of the reversion of land to original ecosystems at the end of the bioenergy program. Depending on whether one counts the climate impacts of any reversion of land uses, and how one values future climate-change impacts relative to present impacts, one can estimate anywhere from zero to very large climate impacts due to land-use change (LUC). The author argues that the best method is to estimate the net present value (NPV) of the impacts of climate change due to LUC. With this approach, one counts the reversion impacts at the end of the program and applies a continuous discounting function to future impacts to express them in present terms. In this case, the impacts of CO_2 emissions from the initial LUC then are at least partially offset by the impacts of CO_2 sequestration from reversion.

12/01040 An investigation into the energy use in relation to yield of traditional crops in central Himalaya, India
Chandra, A. *et al. Biomass and Bioenergy*, 2011, 35, (5), 2044–2052.
Agrobiodiversity and agroecosystem management have changed in central Himalaya due to increasing emphasis on market economy and the motive 'maximization of profit'. Such changes have benefited local people in economic terms, but at the same time increased their vulnerability to environmental and economic risks. The present study addressed the issue of how the ecological functions that are provided by agrobiodiversity translate into tangible benefits for the society. Important characteristics of agrodiversity management are the use of bullocks for draught power, human energy as labour, crop residues as animal feed and animal waste mixed with forest litter as organic input to restore soil fertility levels. The present analysis of resource input–output energy currency in traditional crop production indicated that inputs into different crop systems were significantly higher during kharif season compared to rabi season both under rainfed and irrigated conditions. The maximum input for crop during rabi season (second crop season) was about 31% of that of kharif season (first crop season after fallow) under rainfed conditions. Under irrigated conditions the rabi season input was about 63% of kharif season input. Under rainfed conditions, paddy sole cropping required maximum inputs (231.31 GJ/ha) as compared to mustard sole cropping (11.79 GJ/ha). The present investigation revealed that the total energy inputs and outputs are higher for irrigated agriculture as compared to rainfed system, the difference in inputs is about five-fold and outputs is about two-fold. The output–input ratio showed that irrigated systems have higher values as compared to rainfed systems.

12/01041 Assessment of China's climate commitment and non-fossil energy plan towards 2020 using hybrid AIM/CGE model
Dai, H. *et al. Energy Policy*, 2011, 39, (5), 2875–2887.
China made a commitment in Copenhagen to reduce its carbon dioxide emissions per unit of GDP from 40% to 45% compared with the 2005 level by 2020, and is determined to vigorously develop non-fossil fuels. This study analyses the effects and impacts of policies that could help to achieve China's Copenhagen commitments with a hybrid static CGE model in which the electricity sector is disaggregated into 12 generation technologies. Four scenarios are developed, including the reference scenario A, the reference scenario B and two carbon constraint scenarios. The results show that carbon intensity in terms of GDP will fall by 30.97% between 2005 and 2020 in the reference scenario A, and will be reduced further by 7.97% if China's targeted non-fossil energy development plans can be achieved in the reference scenario B. However, the rest of the 40–45% target must be realized by other measures such as carbon constraint. It is also observed that due to carbon intensity constraints, GDP loss would be from 0.032% to 0.24% compared to the reference scenario B, and CO_2 emission reductions are due mainly to decreases in coal consumption in the electricity sector and manufacturing sector.

12/01042 Calculation of the yearly energy performance of heating systems based on the European Building Energy Directive and related CEN standards
Olesen, B. W. and de Carli, M. *Energy and Buildings*, 2011, 43, (5), 1040–1050.
According to the Energy Performance of Buildings Directive (EPBD) all new European buildings (residential, commercial, industrial, etc.) must since 2006 have an energy declaration based on the calculated energy performance of the building, including heating, ventilating, cooling and lighting systems. This energy declaration must refer to the primary energy or CO_2 emissions. The European Organization for Standardization (CEN) has prepared a series of standards for energy performance calculations for buildings and systems. This paper presents related standards for heating systems. The relevant CEN-standards are presented and a sample calculation of energy performance is made for a small single family house, an office building and an industrial building in three different geographical locations: Stockholm, Brussels, and Venice. The additional heat losses from heating

systems can be 10–20% of the building energy demand. The additional loss depends on the type of heat emitter, type of control, pump and boiler.

12/01043 China's energy security: the perspective of energy users

Bambawale, M. K. and Sovacool, B. K. *Applied Energy*, 2011, 88, (5), 1949–1956.

The article explores the energy security concerns faced by China from the point of view of energy users working in government, university, civil society and business sectors. The authors first derive a set of seven hypotheses related to Chinese energy security drawn from a review of the recent academic literature. They then explain each of these seven hypotheses, relating to (1) security of energy supply, (2) geopolitics, (3) climate change, (4) decentralization, (5) energy efficiency, (6) research and innovation of new energy technologies, and (7) self-sufficiency and trade. Finally, the article tests these hypotheses through a survey distributed in English and Mandarin completed by 312 Chinese participants. The conclusion presents insights for policymakers and energy scholars.

12/01044 Comparative analysis of hourly and dynamic power balancing models for validating future energy scenarios

Pillai, J. R. *et al. Energy*, 2011, 36, (5), 3233–3243.

Energy system analyses on the basis of fast and simple tools have proven particularly useful for interdisciplinary planning projects with frequent iterations and re-evaluation of alternative scenarios. As such, the tool 'EnergyPLAN' is used for hourly balanced and spatially aggregate annual analyses of energy scenarios. For the relatively fast dynamics of electrical energy systems, additional requirements need to be formulated to justify the technical feasibility of the respective scenario. In this article, the comparison is made of energy scenarios for the Danish island of Bornholm. First, the model is verified on the basis of the existing energy mix on Bornholm as an islanded energy system. Future energy scenarios for the year 2030 are analysed to study a feasible technology mix for a higher share of wind power. Finally, the results of the hourly simulations are compared to dynamic frequency simulations incorporating the vehicle-to-grid technology. The results indicate how the EnergyPLAN model may be improved in terms of intra-hour variability, stability and ancillary services to achieve a better reflection of energy and power capacity requirements.

12/01045 CO_2 emissions, GDP and energy intensity: a multivariate cointegration and causality analysis for Greece, 1977–2007

Hatzigeorgiou, E. *et al. Applied Energy*, 2011, 88, (4), 1377–1385.

This paper deals with the causal relationship analysis between gross domestic product, energy intensity and CO_2 emissions in Greece from 1977 to 2007, by means of Johansen cointegration tests and Granger-causality tests based on a multivariate vector error correction modelling. Results indicate that there is a set of uni-directional and bi-directional causalities among the selected time series. The authors performed a model variance decomposition analysis using Choleski technique and provided a comparison with other studies. The findings of the study have significant policy implications for countries like Greece as the decoupling of CO_2 emissions and economic growth seems quite unlikely.intensity

12/01046 Energy consumption and economic growth: new insights into the cointegration relationship

Belke, A. *et al. Energy Economics*, 2011, 33, (5), 782–789.

This paper examines the long-run relationship between energy consumption and real GDP, including energy prices, for 25 OECD countries from 1981 to 2007. The distinction between common factors and idiosyncratic components using principal component analysis allows one to distinguish between developments on an international and a national level as drivers of the long-run relationship. Indeed, cointegration between the common components of the underlying variables indicates that international developments dominate the long-run relationship between energy consumption and real GDP. Furthermore, the results suggest that energy consumption is price-inelastic. Causality tests indicate the presence of a bi-directional causal relationship between energy consumption and economic growth.

12/01047 Energy policy and European utilities' strategy: lessons from the liberalisation and privatisation of the energy sector in Romania

Haar, L. N. and Marinescu, N. *Energy Policy*, 2011, 39, (5), 2245–2255.

In the context of energy sector reforms pursued by Romanian government since 1990s, this study compares and contrasts the market outcomes of European utilities' investment with the host government policy objectives. The study begins with energy market reform in Romania and reviews governments' efforts to attract foreign direct investment (FDI) and to gradually withdraw from the distribution and supply segments of electricity market. Subsequently, there is an illustration of the scope European utilities have had, market policy and design notwithstanding, for consolidating market power through regional dominance. The study goes on to examine the extent to which these utilities have sought to enhance their positions through horizontal and vertical integration, counter to the EU plans for a competitive market structure. It was found that the investments of European incumbents have not been resoundingly successful: although market entrance may have been justified on long-term strategic grounds, in the immediate term, segments acquired through competitive auctions have yielded modest regulated returns. Finally, the authors discuss the extent to which policy makers have achieved their goals. Although the short-term benefits of a competitive market structure have reached some consumers, a renewed interest in promoting 'national champions' reflect frustration with market mechanisms as a means of ensuring long-term strategic investments in the sector.

12/01048 Fuel subsidy in Nigeria: fact or fallacy

Nwachukwu, M. U. and Chike, H. *Energy*, 2011, 36, (5), 2796–2801.

Opinions have differed sharply in Nigeria on the continued existence of fuel subsidy. The opponents of government-planned removal of fuel subsidy argue that the existence of fuel subsidy is a fallacy. On the other hand, the proponents opine that the existence of fuel subsidy is a fact. The objective of this study is to empirically examine these claims and counter-claims. It is therefore hypothesized that there is no significant relationship between fuel demand and fuel subsidy factors. Multiple linear regression was used to test the research hypothesis. The result suggests that there is a significant relationship between the fuel demand and fuel subsidy factors (fuel subsidy, and price of fuel), at 0.01 level ($R^2 = 50.4$). This implies that fuel subsidy factors accounted for 50.4% changes in demand for fuel. This result is empirical evidence that fuel subsidy is a fact and not a fallacy. This study recommends a gradually controlled withdrawal of fuel subsidy at the level it will be minimally harmful to the economy.

12/01049 General equilibrium, electricity generation technologies and the cost of carbon abatement: a structural sensitivity analysis

Lanz, B. and Rausch, S. *Energy Economics*, 2011, 33, (5), 1035–1047.

Electricity generation is a major contributor to carbon dioxide emissions, and abatement in this sector is a key determinant of economy-wide regulation costs. The complexity of an integrated representation of economic and electricity systems makes simplifying assumptions appealing, but there is no evidence in the literature on how important the pitfalls may be. The aim of this paper is to provide such evidence, drawing on numerical simulations from a suite of partial and general equilibrium models that share common technological features and are calibrated to the same benchmark data. The authors report two basic findings. First, general equilibrium inter-sectoral effects of an economy-wide carbon policy are large. It follows that assessing abatement potentials and price changes in the electricity sector with a partial equilibrium Marshallian demand can only provide a crude approximation of the complex demand-side interactions. Second, they provide evidence that widely used top-down representations of electricity technologies produce fuel substitution patterns that are inconsistent with bottom-up cost data. This supports the view that the parametrization of substitution possibilities with highly aggregated production functions is difficult to validate empirically. The overall picture that emerges is one of large quantitative and even qualitative differences, highlighting the role of key structural assumptions in the interpretation of climate policy projections.

12/01050 Growth effects of carbon policies: applying a fully dynamic CGE model with heterogeneous capital

Bretschger, L. *et al. Resource and Energy Economics*, 2011, 33, (4), 963–980.

The paper develops a new type of computable general equilibrium (CGE) model in which growth is fully endogenous, based on the increasing specialization of sector-specific capital varieties. The model is used to simulate the effects of carbon policies on consumption, welfare, and sectoral development in the long run. The benchmark scenario is calculated based on endogenous sector-specific gains from specialization, which carry over to the simulations of a carbon policy following the 2 °C target. Applying the model to the Swiss economy, the authors find that carbon policy leads to growth rates of knowledge intensive sectors that are higher than in the benchmark and that all the non-energy sectors show positive growth rates. Compared to a state in which climate change has no negative effect, consumption in 2050 is reduced by 4.5% and entails a moderate but not negligible welfare loss.

12/01051 Hydrogen energy system analysis for residential applications in the southern region of Algeria

Bendaikha, W. *et al. International Journal of Hydrogen Energy*, 2011, 36, (14), 8159–8166.

The paper is concerned with an hydrogen energy system analysis for residential applications in Ghardaia (southern region of Algeria). This system is based on proton exchange membrane fuel cell (PEMFC) technology, which is supplied by a fuel reforming process, for producing hydrogen fuel starting from natural gas. The exhaust heat is recovered by a thermal storage tank (TST), which is used in an absorption sub-system as a generator for residential cooling systems. The feasibility analysis of an absorption cooling device, using the thermal energy of a PEMFC sub-system for a residential application was carried out at the unit of applied research in renewable energy in Ghardaia. Electrical and thermal power generated by the PEMFC sub-system with variable electrical loads (part load ratio) have been analysed. The feasibility study shows that using PEMFC for residential cooling in Ghardaia is a promising solution. It shows that the temperature of the TST is sufficient to supply the absorption sub-system with a coefficient of performance equals to 0.72 and, the efficiency of the HES equals to 97%.

12/01052 Impact of biofuel production and other supply and demand factors on food price increases in 2008

Mueller, S. A. *et al. Biomass and Bioenergy*, 2011, 35, (5), 1623–1632.

The prices of some grain commodities more than doubled from March 2007 to March 2008. Increased food prices coincided with increasing global biofuel production, leading to speculation that biofuel production was responsible for the increased food prices. However, over the 6-month period after March 2008, grain prices declined by 50% while biofuel production continued to increase. It is not possible to reconcile claims that biofuel production was the major factor driving food price increases in 2007–2008 with the decrease in food prices and increase in biofuel production since mid-2008. The available data suggests that record grain prices in 2008 were not caused by increased biofuel production, but were actually the result of a speculative bubble related to high petroleum prices, a weak US dollar, and increased volatility due to commodity index fund investments. Many factors converged in 2007–2008 to increase food and related commodity prices including increased demand, decreased supply, and increased production costs driven by higher energy and fertilizer costs. Disentangling these factors and providing a precise quantification of their contributions is a difficult, perhaps impossible, task. In 2008, several reports were published by governmental and international agencies that speculated on the cause of increased food prices worldwide. Taken together, the available analyses suggest that biofuel production had a modest (3–30%) contribution to the increase in commodity food prices observed up to mid-2008. The development of second-generation biofuels (e.g. cellulosic ethanol) which use non-food residual biomass or non-food crops should mitigate any future impact of biofuel production on food prices.

12/01053 Options introduction and volatility in the EU ETS

Chevallier, J. *et al. Resource and Energy Economics*, 2011, 33, (4), 855–880.

To improve risk management in the European Union's emissions trading scheme (EU ETS), the European Climate Exchange (ECX) has introduced option instruments in October 2006. The central question this study addresses is: can a potential destabilizing effect of the introduction of options on the underlying market (EUA futures) be identified' Indeed, the literature on commodities futures suggests that the introduction of derivatives may either decrease (due to more market depth) or increase (due to more speculation) volatility. As the identification of these effects ultimately remains an empirical question, daily data is used from April 2005 to April 2008 to document volatility behaviour in the EU ETS. By instrumenting various GARCH models, endogenous break tests, and rolling window estimations, the results overall suggest that the introduction of the option market had the effect of decreasing the level of volatility in the EU ETS while impacting its dynamics. These findings are fairly robust to other likely influences linked to energy and commodity markets.

12/01054 Public perceptions of CCS: emergent themes in pan-European focus groups and implications for communications

Upham, P. and Roberts, T. *International Journal of Greenhouse Gas Control*, 2011, 5, (5), 1359–1367.

This paper reports on European public perceptions of carbon capture and storage (CCS) as determined through six focus groups, one held in each of the UK, the Netherlands, Poland, Germany, Belgium and Spain. The development of opinion and the emergence of concerns were observed via phased exposure to a specially commissioned film providing an overview of CCS technology, its rationale and associated debates, supplemented by additional information on national energy mixes. In general there was a high level of commonality in opinion and concerns across the six countries, with only minor differences. The concerns that emerged were not allayed by the information provided. On the contrary, there was evidence of a shift from initial uncertainty about CCS to negative positions. CCS was generally perceived as an uncertain, end-of-pipe technology that will perpetuate fossil-fuel dependence. Noting the political context to CCS, the authors conclude that advocates will likely find the European public opinion context a challenging one in which to achieve deployment, particularly for onshore storage, except where local communities perceive real economic or other benefits to CCS.

12/01055 Spanish energy roadmap to 2020: socioeconomic implications of renewable targets

Gómez, A. *et al. Energy*, 2011, 36, (4), 1973–1985.

The European Union has established challenging targets for the share of renewable energies to be achieved by 2020; for Spain, 20% of the final energy consumption must be from renewable sources at such time. The aim of this paper is the analysis of the consequences for the electricity sector (in terms of excess cost of electricity, investment requirements, land occupation, CO_2 emissions and overcapacity of conventional power) of several possibilities to comply with the desired targets. Scenarios are created from different hypotheses for energy demand, biofuel share in final energy in transport, contribution of renewables for heating and cooling, renewable electricity generation (generation mix, deployment rate, learning curves, land availability) and conventional power generation (lifetime of current installations, committed deployment, fossil fuel costs and CO_2 emissions cost). A key input in the estimations presented is the technical potential and the cost of electricity from renewable sources, which have been estimated in previous, detailed studies by the present authors using a methodology based on a geographical information system and high-resolution meteorological data. Depending on the scenario, the attainment of the targets will lead to an increase in the cost of electricity from 19% to 37% with respect to 2007.

12/01056 Spatial scale and social impacts of biofuel production

van der Horst, D. and Vermeylen, S. *Biomass and Bioenergy*, 2011, 35, (6), 2435–2443.

The prospect of biofuels going 'mainstream' has drawn more attention to the social impacts of the production and use of transport biofuels. Since 2007, many media stories have appeared about alleged negative impacts of biofuels, notably the price of food going up or land-grab by plantation developers. These stories stand in stark contrast with the rosy picture painted by some academics involved in the technical development of bioethanol or biodiesel. This paper explores the questions when and why negative social impacts are likely to occur and under what circumstances more positive impacts might be expected. These impacts are discussed for three geographically defined biofuel supply chains; north–north, south–north and south–south. These three systems differ in the spatial scale of production and consumption and with that comes a different distribution of environmental, social and economic impacts. In the case of domestic production and consumption in developed countries, the social impacts are relatively minor and can be mitigated by social policies. Large scale, export-oriented production systems in developing countries could theoretically yield positive social impacts, but this would require on the one hand the tailored design of 'pro-poor' social innovations and interventions on the ground and on the other hand a certification of the supply chain feeding into consumer demand for 'ethical' fuel. The latent existence of this demand might be significant but recent NGO campaigns have severely undermined the ethical credentials of biofuels. It would require a persistent and collaborative effort to restore the brand value of 'green' fuel, an effort which will require better legislation and radically improved monitoring and enforcement practices in countries where the very absence of these has led to, and is still causing, the large scale destruction of habitats that are carbon sinks of global importance. The significant levels of government funding for biofuels stand in strong contrast with the problematic environmental and social governance of international biofuels supply chains. Notwithstanding the 'must tackle climate change' rhetoric by policy makers and in policy documents, this suggests that biofuels policy may be primarily driven by other concerns, especially regarding energy security. The authors argue that policies that are designed for a rather narrowly defined purpose of 'security of supply?, cannot be realistically expected to yield high social or environmental benefits, and certainly not abroad.

12/01057 Supply of renewable energy sources and the cost of EU climate policy

Boeters, S. and Koornneef, J. *Energy Economics*, 2011, 33, (5), 1024–1034.

What are the excess costs of a separate 20% target for renewable energy as a part of the European Union's climate policy for 2020? This question is addressed using a computable general equilibrium model, WorldScan, which has been extended with a bottom-up module of the electricity sector. The model set-up makes it possible to base the calibration directly on available estimates of costs and capacity potentials for renewable energy sources. In the base case simulation, the costs of EU climate policy with the renewables target are 6% higher

than those of a policy without this target. The uncertainty in this estimate is considerable, however, and depends on the assumptions about the availability of low-cost renewable energy: the initial cost level, the steepness of the supply curves and share of renewable energy in the baseline. Within the range explored, the excess costs vary from zero (when the target is not a binding constraint) to 32% (when the cost progression and the initial cost disadvantage for renewable energy are high and its initial share is low).

12/01058 Synergies of scale: a vision of Mongolia and China's common energy future
Borgford-Parnell, N. *Energy Policy*, 2011, 39, (5), 2764–2771.
Energy consumption in China is expected to double over the next 20 years. Addressing the enormous scale of China's energy need and attendant increases in greenhouse gas emissions requires dramatic and rapid rollout of renewable energy technologies. Mongolia has some of the world's best renewable energy resources but the scale of its market cannot tap them efficiently. Developing Mongolia into a significant exporter of renewable energy to China will create synergies of scale moving both countries towards their energy goals, creating jobs, and fostering growth while significantly reducing GHG emissions in the region.

12/01059 Technology forecasting and patent strategy of hydrogen energy and fuel cell technologies
Chen, Y.-H. *et al. International Journal of Hydrogen Energy*, 2011, 36, (12), 6957–6969.
This study presents the technological S-curves that integrate the bibliometric and patent analysis into the logistic growth curve model for hydrogen energy and fuel cell technologies and identifies the optimal patent strategy for the fuel cell industry, including PEMFC, SOFC, and DMFC/DAFC. Empirical analysis is via an expert survey and Co-word analysis using the US Patent and Trademark Office database to obtain useful data. Analytical results demonstrate that the S-curves is a highly effective means of quantifying how technology forecasting of cumulative publication patent number. Analytical results also indicate that technologies for generating and storing hydrogen have not yet reached technological maturity; thus, additional R&D funding is needed to accelerate the development of hydrogen technology. Conversely, fuel cell technologies have reached technological maturity, and related patent strategies include freedom to operate, licensing, and niche inventions. The proposed model can be applied to all high-technology cases, and particularly to new clean technologies. The study includes the limitations of the proposed model and directions for further research.

12/01060 The economic costs of reducing greenhouse gas emissions under a U.S. national renewable electricity mandate
Crane, K. *et al. Energy Policy*, 2011, 39, (5), 2730–2739.
The electricity sector is the largest source of greenhouse gas emissions (GHGs) in the USA. Many states have passed and Congress has considered renewable portfolio standards (RPS), mandates that specific percentages of electricity be generated from renewable resources. The authors perform a technical and economic assessment and estimate the economic costs and net GHG reductions from a national 25% RPS by 2025 relative to coal-based electricity. This policy would reduce GHG emissions by about 670 million metric tons per year, 11% of 2008 US emissions. The first 100 million metric tons could be abated for less than $36/metric ton. However, marginal costs climb to $50 for 300 million metric tons and to as much as $70/metric ton to fulfil the RPS. The total economic costs of such a policy are about $35 billion annually. The authors also examine the cost sensitivity to favourable and unfavourable technology development assumptions. They find that a 25% RPS would likely be an economically efficient method for utilities to substantially reduce GHG emissions only under the favourable scenario. These estimates can be compared with other approaches, including increased R&D funding for renewables or the deployment of efficiency and/or other low-carbon generation technologies.

12/01061 The impacts of solar water heating in low-income households on the distribution utility's active, reactive and apparent power demands
Naspolini, H. F. and Rüther, R. *Solar Energy*, 2011, 85, (9), 2023–2032.
In Brazilian low-income households, water-heating requirements are typically met by electrical showerheads. On average, 73.1% of all residential units in the country are equipped with these resistance-heating devices, with nominal powers ranging from 3 to 8 kW. This situation imposes a considerable burden on the electricity utility companies, since electrical showerheads typically represent the highest load but the lowest utilization (load factor) in a residential consumer unit. Furthermore, typical utilization times coincide with, and contribute to, the electrical power demand peaks in Brazil, rendering these low-cost, high-power electrical devices a high-cost consumer for the electrical system to cater for. For low-income residential consumers, electricity tariffs are subsidized, and utilities must therefore make a considerable investment in infrastructure for a limited return. This study analyses the impacts of solar water heating in low-income households on the distribution utility active, reactive and apparent power demands. The authors have monitored a statistically representative group of low-income residences equipped with a compact domestic solar water heater in Florianopolis – Brazil for 1 year. The authors show that in comparison with identical residential units using electrical showerheads, with the adoption of solar water heating the reductions in the active, reactive and apparent power demands on the distribution utility were 49%, 29% and 49% respectively.

12/01062 Trade and energy consumption in the Middle East
Sadorsky, P. *Energy Economics*, 2011, 33, (5), 739–749.
Over the past 30 years many economies have experienced large increases in economic trade, income and energy consumption. This brings up an interesting question. How do increases in trade affect energy consumption? This study uses panel cointegration data estimation techniques to examine the impact of trade on energy consumption in a sample of eight Middle Eastern countries covering the period from 1980 to 2007. Short-run dynamics show Granger causality from exports to energy consumption, and a bi-directional feedback relationship between imports and energy consumption. Long-run elasticities estimated from FMOLS show that a 1% increase in per capita exports increases per capita energy consumption by 0.11% while a one percent increase in per capita imports increases per capita energy consumption by 0.04%. These results are important in establishing that increased trade affects energy demand in the Middle East in both the short and long-run. This has implications for energy policy and environmental policy.

12/01063 Unconventional gas research initiative for clean energy transition in Europe
Weijermars, R. *et al. Journal of Natural Gas Science and Engineering*, 2011, 3, (2), 402–412.
The clean energy transition and European Union's (EU) 2020 targets require a further shift from coal and oil toward natural gas. As a relatively clean fossil fuel, gas must bridge the transition period required for renewable energy technologies to mature such that larger energy quantities can be economically produced to meet demand. Until then, gas is required in Europe and energy scenarios suggest natural gas consumption will reach 650 bcma in 2020 and 780 bcma in 2030. However, conventional gas production in the EU will decline to 230 bcma in 2020 and 140 bcma in 2030. This means the dependency on intercontinental LNG and pipeline imports will increase further and, by 2030, must account for up to 80% of total gas supply. Consequently, the development of European unconventional gas resources could reduce the required gas imports and would improve security of supply and also reduces the risk of price shock. This paper outlines the imminent decline of Europe's conventional gas production, highlights the potential of unconventional gas resources and advocates the key role of R&D to improve the performance of unconventional gas projects. Delft University of Technology has launched the 'unconventional gas research initiative'. The research framework, vision, aims and targets are outlined in this report.

Energy conservation

12/01064 A comparison study on energy savings and fungus growth control using heat recovery devices in a modern tropical operating theatre
Yau, Y. H. and Ng, W. K. *Energy Conversion and Management*, 2011, 52, (4), 1850–1860.
Fungus growth has always been a problem in hot and humid areas. This particular problem is crucial for operating theatre as it could affect the success rate of operations. Many postoperative fungus infection cases had occurred in the past, and it is generally agreed that air-conditioning system play a very important role in resolving the fungus growth problem. Besides air quality, the energy consumption level of air-conditioning system is also very important. In this study, operating theatre 3 in Putrajaya hospital, Malaysia was chosen as the research subject. The air-conditioning system for operating theatre 3 was redesigned with the energy recovery wheel, desiccant dehumidifier and heat pipe heat exchanger to achieve the objectives of this study. A computer program called TRNSYS was utilized for analysis in this research. From the outcome of simulations, it was found that the heat pipe heat exchanger could reduce the most energy consumed by the air-conditioning system. It managed to reduce the energy consumption by 57.85%. Moreover, the payback period of the device is only 0.95 years,

which is the shortest among all the systems studied. Therefore, applying heat pipe heat exchanger is a good choice to save energy and resolve fungus growth problem in hot and humid areas.

12/01065 A performance-based method for energy efficiency improvement of buildings

Chua, K. J. and Chou, S. K. *Energy Conversion and Management*, 2011, 52, (4), 1829–1839.

Building energy standards provide control over excessive use of energy in buildings, promoting energy efficiency and mitigating detrimental environment impacts brought by high energy consumption. The central objective of this paper is to develop correlations that will predict building heat gains and cooling energy consumption for commercial buildings in tropical climates. The energy performance index OTTV was first revised to obtain a new performance index, envelope thermal transfer value (ETTV) for commercial buildings. The authors developed new correlations to investigate the impact ventilation rates and building aspect ratios had on building cooling energy consumption. Comparing estimated and simulated results, good agreement, even for buildings having different aspect ratios, was demonstrated. A study was further conducted to investigate the impact of weather conditions on the developed methodology for estimating the energy consumption of buildings. A design-day weather file was employed to provide simplicity, flexibility and greater ease of use. The design day concept is pivotal in providing key inputs to the cooling energy-estimating methodology yielding good agreement with DOE-2.1E simulated results. The authors believe that the results presented in this study will benefit building authorities in their pursuit of developing and refining stringent building energy standards in order to realize better energy efficient buildings.

12/01066 Drying control system for spray booth with optimization of fuel consumption

Ogonowski, Z. *Applied Energy*, 2011, 88, (5), 1586–1595.

Two-layer control system of the spray booth is presented. Special attention is paid to the upper layer which optimizes operating point of the direct control layer to minimize the fuel consumption. The minimization is done on-line using measurements of the process variables and off-line identified models. In this way the actual distance to the limits of the process variables can be determined and the constraints can be shifted accordingly to determine a new set-point for the direct control layer. This algorithm assures safe performance of the system and minimizes the fuel consumption.

12/01067 Economic evaluation of latent heat thermal energy storage using embedded thermosyphons for concentrating solar power applications

Robak, C. W. *et al. Solar Energy*, 2011, 85, (10), 2461–2473.

An economic evaluation of a latent heat thermal energy storage (LHTES) system for large scale concentrating solar power (CSP) applications is conducted. The concept of embedding gravity-assisted wickless heat pipes (thermosyphons) within a commercial-scale LHTES system is explored through use of a thermal network model. A new design is proposed for charging and discharging a large-scale LHTES system. The size and cost of the LHTES system is estimated and compared with a two-tank sensible heat energy storage (SHTES) system. The results suggest that LHTES with embedded thermosyphons is economically competitive with current SHTES technology, with the potential to reduce capital costs by at least 15%. Further investigation of different phase change materials (PCMs), thermosyphon working fluids, and system configurations has the potential to lead to designs that can further reduce capital costs beyond those reported in this study.

12/01068 Economics of electricity and heat production by gasification or flash pyrolysis of short rotation coppice in Flanders (Belgium)

Voets, T. *et al. Biomass and Bioenergy*, 2011, 35, (5), 1912–1924.

Short rotation coppice (SRC) seems attractive as an energy crop on degraded land. Gasification and flash pyrolysis are promising technologies for the conversion of SRC into energy or chemicals. A model has been developed to calculate the net present value (NPV) of the cash flows generated by an investment in gasification or flash pyrolysis of SRC for the production of electricity or for combined heat and power production. The NPV has been calculated and compared for (combined heat and) power stations with an electrical capacity (P_e) between 5 MW and 20 MW. Furthermore the minimal amount of heat that has to be sold to make combined heat and power production more profitable than pure electricity production has been determined. By performing Monte Carlo simulations, key variables that influence the NPV have been identified. In the case of small scale SRC conversion, i.e. at an electrical capacity of 5–10 MW, flash pyrolysis is more profitable than gasification. At the smallest scale of 5 MW it is necessary to invest in combined heat and power production, as the sole production of electricity is not profitable at this low scale. At an electrical capacity of 10 MW flash pyrolysis for the sole production of electricity becomes profitable, but gasification for electricity production is still not viable. At this capacity however, the extra investments required in the case of combined heat and power production are already paid back if only 25% of the produced heat can be sold. At a higher capacity of 20 MW, the technology choice becomes unclear taking into account the most uncertain variables, i.e. investment cost parameters and energetic efficiencies.

12/01069 Efficient saving targets of electricity and energy for regions in China

Lee, Y.-C. *et al. International Journal of Electrical Power & Energy Systems*, 2011, 33, (6), 1211–1219.

This paper computes the three major types of efficient electricity, coal, and gasoline oil savings for 27 regions in China during the period 2000–2003. The data envelopment analysis (DEA) with a single output (real GDP) and five inputs (labour, real capital stock, coal consumption, gasoline oil consumption, and electricity consumption) is used to compute the energy-saving targets of each region for each year. The efficient energy-saving ratios of each region in each year are obtained by comparing the actual energy inputs to target energy inputs. The major findings are as follows. (1) The east area contains most of the efficient regions with respect to the three major types of energy in every year during the research period. (2) The east, central, and west areas have 2000–2003 average target saving ratios of coal consumption at 18.58%, 44.00% and 59.80%, gasoline consumption at 13.43%, 22.70% and 45.04%, and electricity consumption at 8.55%, 16.42% and 43.70%, respectively. (3) Compared to the cases of gasoline oil and electricity, coal consumption saving is China's most urgent task.

12/01070 Energy consumption and the potential of energy savings in Hellenic office buildings used as bank branches – a case study

Spyropoulos, G. N. and Balaras, C. A. *Energy and Buildings*, 2011, 43, (4), 770–778.

Energy performance of non-residential buildings and in particular of office buildings used as bank branches is very limited. This paper presents new data from 39 representative bank branches and results from a more in-depth analysis of information from energy audits in 11 typical bank branches throughout Greece. The data was used to derive practical energy benchmarks and assess various energy conservation measures. Accordingly, the average annual total energy consumption is 345 kWh/m^2. The breakdown of the different end-uses reveals that HVAC averages 48% of the final energy consumption, lighting averages 35% and other office and electronic equipment average 17%. The most effective energy conservation measures reach annual energy savings of 56 kWh/m^2 by regulating the indoor set point temperature, while the use of HF electronic ballasts and CFL lamps may save about 22 kWh/m^2 and 29 kWh/m^2 with and without the use of the external marquee sign, respectively.

12/01071 Energy efficiency criteria in uninterruptible power supply selection

Moreno-Munoz, A. *et al. Applied Energy*, 2011, 88, (4), 1312–1321.

With the generalized use of microelectronic devices, server computers and other susceptible equipment, the subject related to power quality (PQ) and its relationship to vulnerability of high performance plants are becoming an increasing concern to the industry. This paper addresses how uninterruptible power supply (UPS), particularly when configured in distributed DC mode, can become an energy efficient (EE) solution in high-tech buildings, especially when integrated with complimentary PQ measures. The paper is based on PQ audits conducted at different high-tech industries over the last years. It was found that the main problems for the equipment installed were voltage sags (or dips). Among all categories of electrical disturbances, voltage sags and momentary interruptions are the nemeses of the automated industrial process. The paper analyses the capabilities of modern electronic power supplies and the convenience of embedded solution. Finally it is addresses the role of the Standards on the protection of electronic equipment and the implications for the final costumer.

12/01072 Energy efficiency labeling of buildings: an assessment of the Brazilian case

do Nascimento Batista, N. *et al. Energy and Buildings*, 2011, 43, (6), 1179–1188.

This paper addresses the application of Energy Efficiency Rating Technical Quality Regulations for Commercial, Service and Government Buildings (RTQ-C) in order to ascertain whether the conventional construction system for buildings complies with these requirements. Additionally, it investigates the contribution of labelling to reducing electricity consumption by the building. To do so, the RTQ-C was applied to two buildings in order to calculate the efficiency levels of their envelopes and possible alterations are proposed for upgrading the envelope performance where pertinent. It is noted that conventional buildings adopting measures such as painting the walls

and roof white, in addition to using smoked glass, are sufficient to bring the rating up to an A grade. As no specific concern was noted in the architectural designs for the buildings studied, making use of design strategies that minimize the use of electricity in these buildings, the findings of these case studies may well indicate that the RTQ-C has adopted technical requirements that are not particularly stringent. Consequently, it is believed that these requirements should be reviewed during a second stage, in order to make them more restrictive and attain further improvements in the constructed environment with better energy efficiency for buildings.

12/01073 Energy efficiency public lighting management in the cities

Radulovic, D. *et al. Energy*, 2011, 36, (4), 1908–1915.
Cities all around the world are faced with a rapid increase of urban population, and their crucial sustainable development issue becomes energy management. Moreover, the national energy management sector is slowly passing from government surveillance to the responsibility of local municipalities. The energy efficiency management in cities helps local governments to focus on important energy projects that have strong environmental aspects and financial feasibility. This paper analyses the public lighting energy management in the Croatian city of Rijeka in order to determine the connection of the energy market liberalization and sustainable development in urban areas. Research results indicate a significant connection between investments in energy management of public lighting and its influence on lower emissions of carbon dioxide.

12/01074 Energy losses and heat transfer enhancement in transversally corrugated pipes

Talay Akyildiz, F. *et al. International Journal of Heat and Mass Transfer*, 2011, 54, (15–16), 3801–3806.
Wall friction, temperature distribution and heat transfer through pipe walls are investigated in forced convection with Newtonian fluids in pressure gradient driven hydrodynamically and thermally fully developed steady laminar flow in transversally corrugated pipes. Novel analytical solutions derived via the epitrochoid conformal mapping are presented for the velocity and temperature fields. Analytical results are compared with numerical solutions obtained using the finite volume technique. The effect of the corrugation amplitude and the number of waves on the friction factor, the temperature distribution and the Nusselt number is discussed.

12/01075 Energy renovation of single-family houses in Denmark utilising long-term financing based on equity

Kragh, J. and Rose, J. *Applied Energy*, 2011, 88, (6), 2245–2253.
This paper aims to present an economic overview of the opportunities for energy renovation of single-family houses in Denmark financed over the long term. The paper focuses on the economic difference between energy savings and the repayment of investment. Taking out the average remaining 20% equity in long-term property mortgage loans and utilizing it for extensive energy renovation improves both the economy and the extent of included measures. Approximately 30% of energy consumption in Denmark is used for space heating. The existing 1 million single-family houses account for approximately half of this, thus making energy renovation a key factor for the reduction of CO_2 emissions. The conclusions were that in average the possible budget for renovation varied between €20,000 and €40,000 per single-family house. The equity of the house was particularly dependant on geographical location and construction period. Different energy renovation measures were analysed in terms of economy showing that a wide range of specific measures had a positive economic balance for the homeowner from year 1. The economic balance between saved energy and repayment of the investment is however very dependent on the assumed future energy price. An example showed that a typical house from 1925, still in its original form, could yield annual savings for the homeowner of approximately €2600, assuming a future energy price of 0.2 €/kW h. At the current energy price level of 0.1 €/kW h energy renovation in general is almost economically neutral for the homeowner.

12/01076 Evaluating and ranking energy performance of office buildings using grey relational analysis

Lee, W.-S. and Lin, Y.-C. *Energy*, 2011, 36, (5), 2551–2556.
Traditional methods of evaluating energy performance of building tend to focus on comparing the observed energy consumption with the average value of energy consumption by regression method or theoretical value calculated by simulation analysis. For evaluating and ranking the energy performance of buildings, this paper proposed a perspective of multiple objective outputs to evaluate the energy performance of buildings and then use a multiple attribute decision-making approach, grey relational analysis (GRA), to rank the evaluated buildings. The energy performance of 47 office buildings in Taiwan were evaluated and ranked to serve as a case study to illustrate the procedure and effectiveness of the proposed approach.

12/01077 Evaluating renewable portfolio standards and carbon cap scenarios in the U.S. electric sector

Bird, L. *et al. Energy Policy*, 2011, 39, (5), 2573–2585.
This report examines the impact of renewable portfolio standards (RPS) and cap-and-trade policy options on the US electricity sector. The analysis uses the National Renewable Energy Laboratory's Regional Energy Deployment System (ReEDS) model that simulates the least-cost expansion of electricity generation capacity and transmission in the USA to examine the impact of a variety of emissions caps – and RPS scenarios both individually and combined. The generation mix, carbon emissions, and electricity price are examined for various policy combinations simulated in the modelling.

12/01078 Generalized charts of energy storage effectiveness for thermocline heat storage tank design and calibration

Li, P. *et al. Solar Energy*, 2011, 85, (9), 2130–2143.
Solar thermal energy storage is important to the daily extended operation and cost reduction of a concentrated solar thermal power plant. To provide industrial engineers with an effective tool for sizing a thermocline heat storage tank, this paper used dimensionless heat transfer governing equations for fluid and solid filler material and studied all scenarios of energy charge and discharge processes. It has been found that what can be provided through the analysis is a series of well-configured general charts bearing curves of energy storage effectiveness against four dimensionless parameters grouped up from the storage tank dimensions, properties of the fluid and filler material, and operational conditions (such as mass flow rate of fluid and energy charge and discharge periods). As the curves in the charts are generalized, they are applicable to general thermocline heat storage systems. Engineers can conveniently look up the charts to design and calibrate the dimensions of thermocline solar thermal storage tanks and operational conditions, without doing complicated modelling and computations. It is of great significance that the generalized charts will serve as tools for thermal energy storage system design and calibration in energy industry.

12/01079 Heat pipe based cold energy storage systems for datacenter energy conservation

Singh, R. *et al. Energy*, 2011, 36, (5), 2802–2811.
In the present paper, design and economics of the novel type of thermal control system for a data centre using heat pipe based cold energy storage has been proposed and discussed. Two types of cold energy storage system namely: ice-storage system and cold-water storage system are explained and sized for a data centre with heat output capacity of 8800 kW. Basically, the cold energy storage will help to reduce the chiller running time that will save electricity costs and decrease greenhouse gas emissions resulting from the electricity generated from non-renewable sources. The proposed cold-energy storage system can be retrofit or connected in the existing data centre facilities without major design changes. Out of the two proposed systems, ice-based cold energy storage system is mainly recommended for data centres which are located in very cold locations and therefore can offer long-term seasonal storage of cold energy within reasonable cost. One of the potential application domains for ice-based cold energy storage system using heat pipes is the emergency backup system for the data centre. Water-based cold energy storage system provides more compact size with short-term storage (hours to days) and is potentially useful for data centres located in areas with yearly average temperature below the permissible cooling water temperature ($\sim$25 °C). The aforesaid cold energy storage systems were sized on the basis of metrological conditions in Poughkeepsie, New York. As an outcome of the thermal and cost analysis, water-based cold energy storage system with cooling capability to handle 60% of a data centre's yearly heat load will provide an optimum system size with minimum payback period of 3.5 years. Water-based cold energy storage system using heat pipes can be essentially used as precooler for chiller. Preliminary results obtained from the experimental system to test the capability of heat-pipe-based cold energy storage system have provided satisfactory outcomes and validated the proposed system concept.

12/01080 Implementation of energy efficiency standards of household refrigerator/freezer in China: potential environmental and economic impacts

Tao, J. and Yu, S. *Applied Energy*, 2011, 88, (5), 1890–1905.
Due to the rapid economic development, living standards in China are improving fast. Chinese families are having more household electrical appliances, among which refrigerators are indispensable. Energy consumption of refrigerators is huge in China and causes environmental concerns. China has issued the national energy efficiency standards of household refrigerators, GB12021.2–2003 and GB12021.2–2008 to promote high-efficiency refrigerator production and use. This study evaluated the impacts of the standards on the environment, manufacturers and consumers over a long-term period of 2003–2023. It first evaluated the potential electricity conservation and GHG emission

reduction resulting from energy efficiency improvements driven by the standards. Next, manufacturers' technological and economic concerns about complying with the standards were discussed. Some efficiency improving design options were considered and the resulting increases in manufacturing cost and retail price were estimated. The return of consumers from invest in efficiency was analysed based on lifecycle cost saving of the improved models. The economical viability of the standards was then evaluated by national consumer costs and benefits. Results showed that the considered efficiency standards will potentially save a cumulative total of 588–1180 TWh electricity, and reduce emission of 629–1260 million tons of CO_2, 4.00–8.04 million tons of SO_x and 2.37–4.76 million tons of NO_x by 2023, depending on sale share of models by efficiency. In a more environmentally optimal case (75% sale share of high-efficiency models), the national consumer benefits are 121 billion RMB (discounted), with the benefit/cost ratio of consumer's expenditure being 1.45:1. However, the preference to high-efficiency models is substantial influenced by consumer's expectation on return from the additional cost on efficiency.

12/01081 Modelling of escalator energy consumption

Al-Sharif, L. *Energy and Buildings*, 2011, 43, (6), 1382–1391.

The energy consumed by an escalator can be logically subdivided into two main components. The first component depends on the vertical rise of the escalator and its mechanical and electrical design. This component has been denoted as the fixed power losses. It is the power that is drawn from the supply when the escalator is running unloaded (regardless of the direction of travel). The second component depends on the vertical rise of the escalator and the number of passengers using the escalator per day as well as their walking behaviour. This component has been denoted as the variable power losses for an upward moving escalator (or variable power gains for a downward moving escalator). The formulae used to calculate both components are derived based on power measurements on a large group of escalators in addition to a number of passenger count surveys on a selection of escalators (synchronized to the power measurement data). Further analysis is carried out into the phenomenon of passengers walking on escalators and its effect on the overall energy consumption.

12/01082 Uncertainty, loss aversion, and markets for energy efficiency

Greene, D. L. *Energy Economics*, 2011, 33, (4), 608–616.

Increasing energy efficiency is critical to mitigating greenhouse gas emissions from fossil-fuel combustion, reducing oil dependence, and achieving a sustainable global energy system. The tendency of markets to neglect apparently cost-effective energy efficiency options has been called the 'efficiency gap' or 'energy paradox'. The market for energy efficiency in new, energy-using durable goods, however, appears to have a bias that leads to undervaluation of future energy savings relative to their expected value. This paper argues that the bias is chiefly produced by the combination of substantial uncertainty about the net value of future fuel savings and the loss aversion of typical consumers. This framework relies on the theory of context-dependent preferences. The uncertainty-loss aversion bias against energy efficiency is quantifiable, making it potentially correctible by policy measures. The welfare economics of such policies remains unresolved. Data on the costs of increased fuel economy of new passenger cars, taken from a National Research Council study, illustrate how an apparently cost-effective increase in energy efficiency would be uninteresting to loss-averse consumers.

12/01083 Use of material flow accounting for assessment of energy savings: a case of biomass in Slovakia and the Czech Republic

Kanianska, R. *et al. Energy Policy*, 2011, 39, (5), 2824–2832.

Anthropogenic material and energy flows are considered to be the major cause of many environmental problems we face today. In order to measure material and energy flows, and to mitigate related problems, the technique of material flow and energy flow analysis has been conceived. The aim of this article is to use material and energy flow accounting approaches to quantify the amount of biomass that is available, but that so far has not been used for energy purposes in Slovakia and the Czech Republic and to calculate how much consumed fossil fuels and corresponding CO_2 emissions can be saved by utilizing this biomass. Based on the findings presented, 3544 kt/year of the total unused biomass in Slovakia could replace 53 PJ/year of energy from fossil fuels and 6294 kt/year of the total unused biomass in the Czech Republic could replace 91 PJ/year of energy. Such replacement could contribute to a decrease in total CO_2 emissions by 9.2% in Slovakia and by 5.4% in the Czech Republic and thus contribute to an environmental improvement with respect to climate change.

17 ENERGY CONVERSION AND RECYCLING

12/01084 Biowastes-to-biofuels

Demirbas, M. F. *et al. Energy Conversion and Management*, 2011, 52, (4), 1815–1828.

In recent years, there has been a steadily increasing in the amount of solid waste due to the increasing human population and urbanization. Waste materials are generated from manufacturing processes, industries and municipal solid wastes (MSW). Waste-to-energy (WTE) technologies convert waste matter into various forms of fuel that can be used to supply energy. Today, a new generation of WTE technologies is emerging which hold the potential to create renewable energy from waste matter, including MSW, industrial waste, agricultural waste, and waste byproducts. There are four major methods for conversion of organic wastes to synthetic fuels: (1) hydrogenation, (2) pyrolysis, (3) gasification and (4) bioconversion.

12/01085 Dynamic modeling and optimal control strategy of waste heat recovery organic Rankine cycles

Quoilin, S. *et al. Applied Energy*, 2011, 88, (6), 2183–2190.

Organic Rankine cycles (ORCs) are particularly suitable for recovering energy from low-grade heat sources. This paper describes the behaviour of a small-scale ORC used to recover energy from a variable flow rate and temperature waste heat source. A traditional static model is unable to predict transient behaviour in a cycle with a varying thermal source, whereas this capability is essential for simulating an appropriate cycle control strategy during part-load operation and start and stop procedures. A dynamic model of the ORC is therefore proposed focusing specifically on the time-varying performance of the heat exchangers, the dynamics of the other components being of minor importance. Three different control strategies are proposed and compared. The simulation results show that a model predictive control strategy based on the steady-state optimization of the cycle under various conditions is the one showing the best results.

12/01086 Energy recovery in petrochemical complexes through heat integration retrofit analysis

Feng, X. *et al. Applied Energy*, 2011, 88, (5), 1965–1982.

This paper proposes the principles of how to define a boundary for heat integration in petrochemical complexes that are composed of several interconnected processing units. In order to obtain retrofit schemes that offer significant energy saving potential and are easy to implement, heat integration strategies are also developed in this study. Two case studies based on an aniline plant and an aromatic hydrocarbon plant, each one comprising several processing units, are presented to illustrate the application of these principles and strategies. The boundary for heat integration in each plant can be the whole plant or its individual processing units, the choice of which is determined by their energy saving potentials. Based on energy saving potential, each processing unit in the aniline plant was selected as the boundary for heat integration. The boundary for heat integration in the aromatic hydrocarbon plant, by contrast, was the whole plant. Retrofit schemes for the heat exchanger networks of the two plants, developed using pinch analysis, revealed that significant heating utility savings could be realized with a small number of network structure modifications.

12/01087 The potential of wastewater heat and exergy: decentralized high-temperature recovery with a heat pump

Meggers, F. and Leibundgut, H. *Energy and Buildings*, 2011, 43, (4), 879–886.

There is a large potential in the heat losses from the wastewater leaving a building. This paper presents a novel concept for recovering this heat. Instead of recovering it in a mixed state, the recovery immediately after use is evaluated. This allows the exploitation of the higher temperatures found at the points of warm water usage. By integrating a heat pump to utilize this heat, a higher temperature heat supply can be obtained while maintaining a low temperature-lift requirement. This leads to the possibility of directly regenerating the hot water supply through wastewater heat recovery. The concept is a result of research into low exergy building systems, and is part of the IEA ECBCS Annex 49. The authors have modelled the annual performance of two different system scenarios, which result in a potential average annual coefficient of performance (COP) of over six. The first scenario supplies up to 4400 kWh of heat for all hot water events with only 790 kWh of electricity, while the second scenario regenerated directly the hot water supply just for bathroom fixtures at 2400 kWh with just 410 kWh of energy. This is a significant reduction in the demand for hot water supply of a building compared to most modern installations.

12/01088 Waste to energy by industrially integrated supercritical water gasification – effects of alkali salts in residual by-products from the pulp and paper industry
Rönnlund, I. *et al*. *Energy*, 2011, 36, (4), 2151–2163.
Supercritical water gasification (SCWG) is a method by which biomass can be converted into a hydrogen-rich gas product. Wet industrial waste streams, which contain both organic and inorganic material, are well suited for treatment by SCWG. In this study, the gasification of two streams of biomass resulting from the pulp and paper industry, black liquor and paper sludge, has been investigated. The purpose is to convert these to useful products, both gaseous and solids, which can be used either in the papermaking process or in external applications. Simple compounds, such as glucose, have been fully gasified in SCWG, but gasification of more complex compounds, such as biomass and waste, have not reached as high conversions. The investigated paper sludge was not easily gasified. Improving gasification results with catalysts is an option and the use of alkali salts for this purpose was studied. The relationship between alkali concentration, temperature, and gasification yields was studied with the addition of KOH, K_2CO_3, NaOH and black liquor to the paper sludge. Addition of black liquor to the paper sludge resulted in similarly enhancing effects as when the alkali salts were added, which made it possible to raise the dry matter content and gasification yield without expensive additives.

12/01089 Wet and dry cooling systems optimization applied to a modern waste-to-energy cogeneration heat and power plant
Barigozzi, G. *et al*. *Applied Energy*, 2011, 88, (4), 1366–1376.
In Brescia, Italy, heat is delivered to 70% of 200,000 city inhabitants by means of a district heating system, mainly supplied by a waste to energy plant, utilizing the non-recyclable fraction of municipal and industrial solid waste (800,000 tons/year, otherwise landfilled), thus saving annually over 150,000 tons of oil equivalent and over 400,000 tons of carbon dioxide emissions. This study shows how the performance of the waste-to-energy cogeneration plant can be improved by optimizing the condensation system, with particular focus on the combination of wet and dry cooling systems. The analysis has been carried out using two subsequent steps: in the first one a schematic model of the steam cycle was accomplished in order to acquire a knowledge base about the variables that would be most influential on the performance. In the second step the electric power output for different operating conditions was predicted and optimized in a homemade program. In more details, a thermodynamic analysis of the steam cycle, according to the design operating condition, was performed by means of a commercial code (Thermoflex) dedicated to power plant modelling. Then the off-design behaviour was investigated by varying not only the ambient conditions but also several parameters connected to the heat rejection rate, like the heat required from district heating and the auxiliaries load. Each of these parameters has been addressed and considered in determining the overall performance of the thermal cycle. After that, a complete prediction of the cycle behaviour was performed by simultaneously varying different operating conditions. Finally, a Matlab computer code was developed in order to optimize the net electric power as a function of the way in which the condensation is operated. The result is an optimum set of variables allowing the wet and dry cooling system to be regulated in such a way that the maximum power is achieved. The best strategy consists in using the maximum amount of heat rejection in the wet cooling system to reduce the operational cost of the dry one.