01 SOLID FUELS

Sources, winning, properties

11/00447 An experimental study of sulphate transformation during pyrolysis of an Australian lignite

Yani, S. and Zhang, D. *Fuel Processing Technology*, 2010, 91, (3), 313–321.

The transformation of sulfate minerals during pyrolysis of an Australian lignite has been studied using pure sulfates ($CaSO_4$, $FeSO_4$ and $Fe_2(SO_4)_3$), a high mineral (HM) lignite sample and a low mineral (LM) lignite sample collected from different locations of the same deposit, and samples of acid-washed LM doped with sulfates ($CaSO_4$+ LM and $FeSO_4$+ LM), respectively. Thermogravimetric analysis and fixed-bed reactor techniques were used for the pyrolysis experimentation and the lignite samples and their chars were analysed using FTIR and XRD. The TGA experiments showed that $CaSO_4$ decomposes between 1400 and 1700 K in nitrogen and a 50/50 N_2/CO_2 mixture, while in air $CaSO_4$ decomposes between 1500 and 1700 K. Using a TGA–MS it was found that only a small fraction of $CaSO_4$ in $CaSO_4$+ LM decomposed at 653 K, releasing SO_2. $CaSO_4$ was still observed in the char recovered at 1073 K as confirmed by the FTIR and XRD analysis. $FeSO_4{\cdot}7H_2O$ released the bound water below 543 K and the remaining $FeSO_4$ decomposed between 813 and 953 K. $FeSO_4$ in $FeSO_4$+ LM decomposed at 500 K to release SO_2. The inherent sulfates in HM were dominated by iron sulfates which started to decompose and release SO_2 at around 500 K and all sulfate had been decomposed at 1073 K. It was observed that during the fixed-bed pyrolysis at 1073 K in nitrogen, approximately 36% of the total sulfur in the $CaSO_4$+ LM decomposed, 88% of the total sulfur in the $FeSO_4$+ LM decomposed and around 76% of the total sulfur in HM decomposed. It was also confirmed that $FeSO_4$+ LM produced more volatile sulfur than $CaSO_4$+ LM during pyrolysis.

11/00448 Comparison of the associative structure of two different types of rich coals and their coking properties

Shui, H. *et al*. *Fuel*, 2010, 89, (7), 1647–1653.

Solvent extractions of two different types of Chinese rich coals, i.e. Aiweiergou coal (AG) and Zaozhuang coal (ZZ) using the mixed solvent of carbon disulfide/N-methyl-2-pyrrolidinone (CS_2/NMP) with different mixing ratios were carried out and the caking indexes of the extracted residues were measured. It was found that the extracted residues from the two types of coals showed different changing tendencies of the caking indexes with the extraction yield. When the extraction yield attained about 50% for ZZ coal, the extracted residue had no caking property. However for AG coal, when the extraction yield reached the maximum of 63.5%, the corresponding extracted residue still had considerable caking property with the caking index of 25. This difference indicated the different associative structure of the two coals although they are of the same coalification. Hydro-thermal treatment of the two rich coals gave different extract fractionation distributions for the treated coals compared to those of raw coals respectively. The coking property evaluations of the two coals and their hydro-thermally treated ones were carried out in a crucible coking determination. The results showed that the hydro-thermal treatment could greatly improve the micro-strengths of the resulting coke from the two coals, and the improvement was more significant for the more aggregated AG coal. The reactivities of hydro-thermally treated AG coal blends were almost the same as those of raw coal blends. The higher coke reactivities of AG raw coal and its hydro-thermally treated ones than those of ZZ coal might be attributed to its special ash composition.

11/00449 Determining the molecular weight distribution of Pocahontas No. 3 low-volatile bituminous coal utilizing HRTEM and laser desorption ionization mass spectra data

Mathews, J. P. *et al*. *Fuel*, 2010, 89, (7), 1461–1469.

Knowledge of the molecular weight distribution is important for rationalizing coal behaviour. While many analytical approaches generate average data, inclusion of coal's inherent structural diversity would improve molecular representations of coal and their usefulness. The molecular weight distribution of Pocahontas No. 3 coal was estimated based on a new approach coupling HRTEM lattice fringe image data and laser desorption ionization mass spectra (LDIMS), constrained by elemental and NMR data. Assuming a shape for the large aromatic coal molecules allows the determination of the aromatic raft size distribution, and prediction of the molecular weight distribution from the HRTEM lattice fringe image analyses. Similar-shaped molecular weight profiles were obtained from these different techniques. Both distributions showed a sharp rise, fall and long tail, with the HRTEM profile being shifted to a lower mass in comparison to the LDIMS data. The mean molecular weight of an aromatic raft, 289 Da, was similar to 299 Da a value reported from NMR data. Cross-linking the fringes generated a diverse network structure of aromatic clusters with a reasonable aromatic H/C ratio and a molecular weight distribution within the appropriate ranges from laser desorption data. A rationale for molecular diversity determination, necessary for large-scale molecular modelling, for a high-rank coal is proposed.

11/00450 Distribution of sulfur and pyrite in coal seams from Kutai Basin (East Kalimantan, Indonesia): implications for paleoenvironmental conditions

Widodo, S. *et al*. *International Journal of Coal Geology*, 2010, 81, (3), 151–162.

Thirteen Miocene coal samples from three active open pit and underground coalmines in the Kutai Basin (East Kalimantan, Indonesia) were collected. According to microscopical and geochemical investigations, coal samples from Sebulu and Centra Busang coalmines yield high sulfur and pyrite contents as compared to the Embalut coalmine. The latter being characterized by very low sulfur (<1%) and pyrite contents. The ash, mineral, total sulfur, iron and pyrite contents of most of the coal samples from the Sebulu and Centra Busang coalmines are high and positively related in these samples. Low contents of ash, mineral, total sulfur, iron and pyrite have been found only in sample TNT-32 from Centra Busang coalmine. Pyrite was the only sulfur form that could be recognized under reflected light microscope (oil immersion). Pyrite occurred in the coal as framboidal, euhedral, massive, anhedral and epigenetic pyrite in cleats/fractures. High concentration of pyrite argues for the availability of iron in the coal samples. Most coal samples from the Embalut coalmine show lower sulfur (<1 wt%) and pyrite contents as found within Centra Busang and Sebulu coals. One exception is the coal sample KTD-38 from Embalut mine with total sulfur content of 1.41 wt%. The rich ash, mineral, sulfur and pyrite contents of coals in the Kutai Basin (especially Centra Busang and Sebulu coals) can be related to the volcanic activity (Nyaan volcanic) during Tertiary whereby aeolian material was transported to the mire during or after the peatification process. Moreover, the adjacent early Tertiary deep marine sediment, mafic igneous rocks and melange in the centre of Kalimantan Island might have provided mineral to the coal by uplift and erosion. The inorganic matter in the mire might also originate from the ground and surface water from the highland of central Kalimantan.

11/00451 Mineralogy of lignites and associated strata in the Mavropigi field of the Ptolemais Basin, northern Greece

Koukouzas, N. *et al*. *International Journal of Coal Geology*, 2010, 81, (3), 182–190.

The mineralogy of five lignite layers and the associated roof, floor and intercalating strata has been analysed using low-temperature oxygen-plasma ashing and quantitative X-ray diffraction techniques. The lignite contains quartz, kaolinite, illite and smectite, and in some cases small proportions of feldspar, thought to represent mainly detrital minerals in the original peat deposits. One sample also contains crystalline calcium oxalates, with weddellite present in the raw lignite and whewellite in the low-temperature ash (LTA) of the same lignite sample. Minor proportions of gypsum are present in some of the raw lignite samples, possibly in part derived from precipitation of dissolved Ca and SO_4 in the pore waters on drying. All the LTAs, however, contain much higher proportions of bassanite and/or gypsum compared to the other minerals present, consistent with production of calcium sulfate artefacts from interaction of abundant organically associated Ca and S in the lignite during the plasma-ashing procedure. The inorganic strata are mainly carbonate rocks, consisting almost entirely of calcite with minor aragonite, small proportions of illite, traces of pyrite and in some cases siderite. Some non-carbonate rocks are also associated with the lignite seams; these are dominated by plagioclase feldspar and mica, along with illite, kaolinite and a relatively minor proportion of quartz. The mineral assemblages can be related to the palaeoenvironmental conditions under which the various sediments (including lignite) were deposited. Comparison of the mineral abundances in the samples to the chemical composition of the materials shows that the quantitative XRD technique provides results consistent with ash analysis data. Although abundant in the associated rocks, calcite does not occur in the lignite samples. While part of the relatively abundant Ca in the lignite occurs as either gypsum or weddellite, most of it appears to be organically bound. Mine products that incorporate calcareous rocks of the type associated with the lignite may, however, contain separate calcite phases and display high carbonate CO_2 contents.

11/00452 Modeling of solid fuels combustion in oxygen-enriched atmosphere in circulating fluidized bed boiler: part 1. The mathematical model of fuel combustion in oxygen-enriched CFB environment

Krzywanski, J. *et al*. *Fuel Processing Technology*, 2010, 91, (3), 290–295.

This paper focuses on the idea of large-scale circulating fluidized bed (CFB) boiler operation with oxygen/CO_2-modified atmosphere inside combustion chamber. The following main advantages can be found for this technology: reduction of pollutant emissions, possibility of high efficiency separation of CO_2 from the exhaust gases that results from increased CO_2 concentration, lower chimney loss due to the reduction of flue gases in a volume, limitation of the combustion chamber dimensions, etc. The paper presents a model of coal combustion in oxygen-enriched CFB environment, where air staging, desulfurization process, NO_x formation and reduction as well as a stationary dense phase of coarse particles in the bottom part of combustion chamber and a circulating dilute phase in the upper part are included.

11/00453 Petrophysical characterization of coals by low-field nuclear magnetic resonance (NMR)

Yao, Y. *et al. Fuel*, 2010, 89, (7), 1371–1380.

Nuclear magnetic resonance (NMR) has been widely used in petrophysical characterization of sandstones and carbonates, but little attention has been paid in the use of this technique to study petrophysical properties of coals, which is essential for evaluating coalbed methane reservoir. In this study, two sets of NMR experiments were designed to study the pore types, pore structures, porosity and permeability of coals. Results show that NMR transverse relaxation (T_2) distributions strongly relate to the coal pore structure and coal rank. Three T_2 spectrum peaks identified by the relaxation time at 0.5–2.5 ms, 20–50 ms and >100 ms correspond to pores of <0.1 μm, >0.1 μm and cleats, respectively, which is consistent with results from computed tomography scan and mercury intrusion porosimetry. Based on calculated producible and irreducible porosities through a T_2 cutoff time method, a new NMR-based permeability model is proposed that better estimates the permeability of coals. In combination with mercury intrusion porosimetry, a NMR-based pore structure model that efficiently estimates the pore size distribution of coals is also proposed. The new experiments and modelling prove the applicability of NMR in petrophysical characterization of intact coal samples, which has potential applications for NMR well logging in coalbed methane exploration.

11/00454 Radiation attenuation characteristics of pyrolysis volatiles of solid fuels and their effect for radiant ignition model

Zhou, Y. *et al. Combustion and Flame*, 2010, 157, (1), 167–175.

Radiation attenuation characteristics of pyrolysis volatiles from heated solid fuels, a neglected physical effect in radiant ignition process, are studied by simulated experiment and mathematical models. First, it is experimentally found the radiation attenuation of an incident heat flux when pine or polymethyl methacrylate (PMMA) is heated occurs before flaming ignition (6–14%), especially for the one in the experiment of the cone calorimeter-style apparatus with a shorter test radiation distance ($D < 100$ mm). Then, a more reasonable parameter using Beer's law for determining the radiation absorptivity of pyrolysis volatiles of different fuels is presented. It is found the radiation absorptivity of pyrolysis volatiles of PMMA is actually larger than the one of pine and the ignition of PMMA more depends on the gas-phase heating by radiation absorption. Finally, the calculated results with the experimental radiation attenuation data illustrates that consideration of the radiation attenuation by pyrolysis volatiles in radiant ignition models is necessary. A constant radiation attenuation coefficient $G = 0.1$ is approximately accepted for the general calculation of radiant ignition model.

11/00455 Reactivity of pulverized coals during combustion catalyzed by CeO_2 and Fe_2O_3

Gong, X. *et al. Combustion and Flame*, 2010, 157, (2), 351–356.

Effects of CeO_2 and Fe_2O_3 on combustion reactivity of several fuels, including three ranks of coals, graphite and anthracite chars, were investigated using a thermogravimetric analyser. The results indicated that the combustion reactivity of all the samples except lignite was improved with the addition of CeO_2 or Fe_2O_3. It was interesting to note that the ignition temperatures of anthracite were decreased by 50 and 53 °C, respectively, with CeO_2 and Fe_2O_3 addition and that its combustion rates were increased to 15.4% and 12.2%/min. Ignition temperatures of lignite with CeO_2 and Fe_2O_3 addition were 250 and 226 °C, and the combustion rates were 12.8% and 19.3%/min, respectively. When compared with those of lignite without catalysts, no obvious catalytic effects of the two catalysts on its combustion reactivity were revealed. The results from the combustion of the three rank pulverized coals catalysed by CeO_2 and Fe_2O_3 indicated significant effects of the two catalysts on fixed carbon combustion. And it was found that the higher the fuel rank, the better the catalytic effect. The results of combustion from two kinds of anthracite chars showed obvious effects of anthracite pyrolysis catalysed by CeO_2 and Fe_2O_3 on its combustion reactivity.

11/00456 Set up of an experimental apparatus for the study of fragmentation of solid fuels upon severe heating

Senneca, O. *et al. Experimental Thermal and Fluid Science*, 2010, 34, (3), 366–372.

An experimental apparatus was developed in order to perform tests of primary fragmentation of solid fuels under severe heating conditions. The device is a modified heated strip reactor, capable of reaching 2000 °C in less than 0.2 s. Particles are laid on the strip and pyrolysed under inert or moderately oxidizing conditions. The char particles and their fragments, generated on pyrolysis, can be recovered and analysed to assess the fragmentation propensity of the fuel. Some preliminary experiments have been carried out on two biomass samples in order to assess the time–temperature history of particles in the experimental apparatus. In particular, biomass particles of approximately 2–3 mm have been used. The temperature of the heated strip reactor in such preliminary tests was varied between 1000 and 1600 °C, while the strip nominal heating rate was kept at 10^4 °C/s and the holding time was set at the value of 10 s. A near-infrared high-speed camera (38,000 frames/s) was used to measure the temperature of the heated strip and of the particles during the tests. A heat-up model was developed and validated against experimental results. The model was then used to estimate the temperature gradients across particles of biomass and of coal as well. Results show that the strip of the reactor reaches the set temperature in less than 0.2 s. When particles are laid on the strip, their bottom surface, which is in physical contact with the strip, immediately reaches the set temperature value. For 1 mm coal particles the upper surface can be considered at the same temperature as well. Under the most severe conditions tested (strip temperature of 1600 °C, biomass particles of 2 mm thickness) the temperature difference between the bottom and the upper face is 200 °C after 3 s and drops to 100 °C after 10 s. On the whole, the experimental apparatus simulates uniform heating of the particles with reasonable approximation. In the next future the apparatus will be further upgraded to operate at pressures up to 20 bars.

11/00457 Study on the structure and pyrolysis characteristics of Chinese western coals

Wang, J. *et al. Fuel Processing Technology*, 2010, 91, (4), 430–433.

The structure and pyrolysis characteristics of three inertinite-rich Chinese western coals were researched and compared with one relative vitrinite-rich Chinese middle coal by means of XRD, TG–DTG and fixed-bed reactor. The results show that the atomic ratio O/C, aromaticity factor, even ring condensation number and ring condensation index increase and atomic ratio H/C decreases with increasing inertinite content in coal; inertinite contains more aromatic ring structure than that of vitrinite; the crystallite structure order of coal char increases slightly with increasing heat treatment temperature. The higher inertinite content in coal is, the lower pyrolysis reactivity of coal is at lower temperature, and yet they have obvious second pyrolysis reactivity in higher temperature. The pyrolysis reaction in primarily devolatilization phase that comes mainly from the decomposition of containing hydrogen function groups and the secondary devolatilization at high temperature is mainly the decomposition of stable containing oxygen function groups in coal matrix with higher inertinite.

11/00458 Thermogravimetric assessment of combustion characteristics of blends of a coal with different biomass chars

Sahu, S. G. *et al. Fuel Processing Technology*, 2010, 91, (3), 369–378.

In connection with future energy demand and the fossil fuel crisis, particularly in India, biomass is gaining importance as a possible co-fuel. In India, varieties of biomass products are available which do have tremendous potentiality for co-combustion with pulverized coal. Based on the emerging need, detailed investigations are felt necessary to examine the compatibility of different kind of biomass with coal and to select suitable blend composition(s) before utilizing those biomass products in utility operation as co-fuels. This study elaborates the laboratory-scale findings of combustion experiments in DSC–TGA apparatus with a typical Indian coal, two biomass samples and low temperature biomass chars (300 and 450 °C) as well as with blends of low temperature chars and coal. Conventional TGA parameters, activation energy and ignition index of different blends were estimated which provided elaborate information on their basic combustion features. Results of non-isothermal combustion studies in general depict that blends containing less than 50% biomass char are better performing as compared those with higher biomass char content. Lowering of activation energy and improvement of reactivity in major combustion zone were also observed in the coal/biomass-char blends. Improvement of ignition index of the blends of coal with 300 °C chars over expected weighted mean values was noticed. Such attempts may help to identify appropriate biomass-type, blend proportion for a given coal and to derive some specific advantages with respect to particular combustion practice.

Preparation

11/00459 Effect of coal-over-coal reburn on furnace temperature and heat flux distributions in 1 MW tangentially fired furnace

Li, S. *et al. International Journal of Thermal Sciences*, 2010, 49, (1), 225–233.

The furnace temperature and heat flux distributions of 1 MW tangentially fired furnace were studied during coal-over-coal reburn, and the influences of the position of reburn nozzle and reburn fuel fraction on furnace temperature and heat flux distributions were investigated. Compared with the baseline, the flue gas temperature is 70–90 °C lower in primary combustion and 130–150 °C higher at furnace exit, and the variations of the flue gas temperature distributions along furnace height are slower. The temperature distribution along the width of furnace wall decreases with the increase of the relative furnace height. In the primary combustion zone and the reburn zone, the temperature and heat flux distributions of furnace wall are much non-uniform and asymmetric along the width of furnace wall, those of furnace wall in the burnout zone are relatively uniform, and the temperature non-uniformity coefficients of the primary combustion zone, the reburn zone and the burnout zone are 0.290, 0.100 and 0.031, respectively.

11/00460 Fe(III)–humate complexes from Megalopolis peaty lignite: a novel eco-friendly fertilizer

Chassapis, K. *et al. Fuel*, 2010, 89, (7), 1480–1484.

Fe(III)–humate complexes were synthesized from Greek peaty lignite of the Megalopolis Basin. The preparation was carried out under mild and low-energy conditions producing a biodegradable, eco-friendly and effective material to substitute the synthetic chelates Fe–EDDHA, Fe–EDTA and Fe–DTPA. Due to both the existing expanded configuration of the humic substances (that make binding sites accessible to the metal ions) and the ionization of functional groups, alkaline environment facilitates the association between Fe(III) ions and the lignite-derived humic substances. UV–vis and IR spectra revealed coordination of the metal ions with the carboxylic and phenolic groups of the oxygen-rich humic substances. Fe(III)–humate complexes were proved stable in a wide pH range similar to Fe–EDDHA synthetic chelates. Furthermore, the presence of $K^{\pm}$ and humic matter increases the agronomic value of this material establishing alternative applications for Megalopolis peaty lignite.

11/00461 Field trials of aquifer protection in longwall mining of shallow coal seams in China

Zhang, D. *et al. International Journal of Rock Mechanics and Mining Sciences*, 2010, 47, (6), 908–914.

The large-scale mining of shallow coal seams has a significant impact on the overlying aquifers and surface ecological environment. To protect the aquifers and maximize the coal resource recovery, field trials were undertaken during the operation of the LW32201 in Bulianta coal mine, Shendong, China. With a severely weathered rock (SWR) layer and two key strata (KS) in the overlying strata, aquifer protection in longwall mining (APLM) relies mainly on the rapid advance. In some localized zones, special measures should be taken to achieve the APLM, including lowering mining height, backfill and slurry injection. To further understand the mechanism and applicable conditions of the APLM and validate the effectiveness of the APLM, variation of the water table in the aquifer was observed as the longwall face passed through the zone. This paper also discusses the mechanism and basic requirements of the APLM and the relationship between the fall of the water table and the surface subsidence. The results of the field trials indicated that APLM in shallow coal seams could be successful under suitable conditions.

Economics, business, marketing, policy

11/00462 Environmental evaluation for sustainable development of coal mining in Qijiang, western China

Si, H. *et al. International Journal of Coal Geology*, 2010, 81, (3), 163–168.

Environmental degradation associated with mining activities may seriously threaten the health of local people and the sustainable development of coal mining, which may need to be addressed by improved environmental evaluation system. Based on analysing environmental pollution from coal mining and the increasing need for raw coal, this paper establishes an environmental evaluation system, covering environmental situation, resource protection and economic benefit, for sustainable development in coal mining. This paper proposes methods for calculating the weight of each index and the environmental sustainable capability taking into account the method of analytic hierarchy process. Finally, the index system is used to evaluate the environmental sustainability of coal mining in the Qijiang area, western China, which has demonstrated the validity of the index system. It may also be useful as a tool to assess the environmental impact of mining areas, as well as a measure to promote sustainable development in coal mining.

11/00463 Geostatistical coal quality control in longwall mining

Hindistan, M. A. *et al. International Journal of Coal Geology*, 2010, 81, (3), 139–150.

Coal quality is an important aspect of coalmine planning. This paper presents a case study in which an underground coalmine is faced with severe penalty cost because it does not consider *in situ* coal quality control at all. To help short-term planning of the coal production the mean calorific values of the blocks inside the production panels are estimated by kriging. The estimated calorific values are compared with those obtained from actual production. The ratio of the calorific values of actual production to estimated values is found to be 0.73 in average due to adverse effect of dilution on the quality of run-of-mine coal. This study reveals the importance of geostatistical block modelling in short-term mine planning.

11/00464 Lower emission plant using processed low-rank coals

Domazetis, G. *et al. Fuel Processing Technology*, 2010, 91, (3), 255–265.

Low-rank coals can be processed into non-fouling coal, ultra-low ash coal, and coals containing catalysts. Systematic studies of the action of acid to reduce ash in a number of low-rank coals have shown total ash reduction varied from 96% to 30%; the extent of ash reduction was limited by the nature of minerals, which may be removed using various acids, including HF, to produce ultra-low ash coal. A commercial process must operate at elevated temperatures, but this must not produce toxic wastewater; data are provided to show that wastewater may be treated and water recycled without polluting the environment. The addition of effective catalysts results in enhanced reactivity of the coal to oxygen and steam; experimental data show high yield of H_2 from char and steam, and accompanying post-gasification chemistry. Development of catalytic steam gasification requires an understanding of aqua-chemistry and the thermal transformations of inorganics as the coal is heated. The scientific basis exists for processing low-rank coals, but commercial application requires: (i) high production rates, (ii) treating wastewater produced from coal treatment plant, (iii) catalysts that increase the yield of H_2 from steam gasification, and (iv) plant that achieves high power and thermal efficiencies. Modelling studies for super-critical plant, and for direct coal-fuelled turbine in combined cycle, illustrate the potential for lower-emission technology; catalytic steam gasification offers the cleanest option for future coal-fuelled plant.

Derived solid fuels

11/00465 Ash fusibility and compositional data of solid recovered fuels

Dunnu, G. *et al. Fuel*, 2010, 89, (7), 1534–1540.

Several approaches are established to analyse the fouling and slagging propensities of coal ashes, but the same cannot be said of solid recovered fuel (SRF) ashes. This work has been conducted by using some fouling and slagging indicators, which are commonly applicable to coal ashes, on SRF ashes to ascertain their applicability. In this work, laboratory prepared ashes derived from municipal solid waste (MSW), sewage sludge, demolition wood, shredded rubber tyres, and plastic/paper fluff are analysed for their fusibility leading to fouling and slagging using three approaches; the ash fusibility temperatures (AFT), ternary phase diagrams, and fouling/slagging indices. The results from each approach are examined to determine the inclination of the ashes toward fouling and slagging. A subsequent inter-comparison of the methods was conducted to validate the methods which are in agreement and are applicable to SRF ashes. The study showed that ternary equilibrium phase diagram SiO_2–CaO–Al_2O_3, various fouling and slagging indices, and AFT can be used to complement each other to predict ash fusion properties, fouling and slagging propensities of SRF ashes.

11/00466 Catalytic effect of black liquor on the gasification reactivity of petroleum coke

Zhan, X. *et al. Applied Energy*, 2010, 87, (5), 1710–1715.

CO_2 gasification of petroleum coke using black liquor as a catalyst was performed in a thermogravimetric analyser (TGA) under temperatures 1223–1673 K at ambient pressure to evaluate the effect of black liquor loading on petroleum coke gasification. It was found that the gasification reactivity of petroleum coke was improved greatly by black liquor. The gasification reactivity was affected by different loading methods in the order: wet grinding > dry grinding > physical impregnation > dry mix. The catalytic activity of black liquor was higher than that of pure alkali metal. The effect of temperature on the gasification reactivity of petroleum coke was changed by black liquor. The reactivity reaches its maximum at 1573 K. The reactivity of petroleum coke was found higher than that of Shenfu coal when black liquor loading is 5 wt% (of petroleum coke), clearly demonstrating that black liquor could be an effective catalyst for petroleum coke gasification.

11/00467 Char oxidation study of sugar cane bagasse, cotton stalk and Pakistani coal under 1% and 3% oxygen concentrations

Daood, S. S. *et al. Biomass and Bioenergy*, 2010, 34, (3), 263–271.

Chars of sugar cane bagasse (1 & 2), Cotton stalk and low rank Pakistani coal have been studied by TGA under low oxidative environments with O_2 concentrations of 1% and 3%. The maximum reactivity of the chars was found to be greater by a factor of 2 under 3% oxygen compared to 1% O_2 conditions. Overall conversion levels at 3% O_2 for sugar cane bagasse-2 increased from 63% to 100%, sugar cane bagasse-1; 54% to 97%, cotton stalk; 45% to 100% and Pakistani coal; 63% to 90% in comparison to 1% O_2. The maximum average rate of weight loss was found in Region III compared to Region I and II supported by CO/CO_2 FTIR Chemigram analysis. On the other hand, % conversion was maximum in Region II under 1% and 3% O_2 concentration. Overall average rates of weight losses were dependent on O_2 concentration and temperature ranges, however for all the regions % conversion and average weight loss were twice in 3% compared to 1% O_2 concentration. Biomass chars were found to be more reactive than the coal studied here during each region of the oxidation process. Evaluated apparent energy of activations for biomass chars was found within range of 41.2–105.8 kJ mole^{-1} under 1%, 46.9–125.6 kJ mole^{-1} under 3% compared to coal; 70.3–183.9 kJ mole^{-1} under 1% and 83.1–167.4 kJ mole^{-1} in 3% O_2 concentration for order of reaction (n) varying between $0.5 \leq n \leq 2$. From the tests carried under O_2 levels of 1% and 3%, it is possible to give the following sequence to the apparent activation energies under any of the fixed value of n, obtained for the biomasses and coal; Pakistani coal > cotton stalk > sugar cane bagasse-2 > sugar cane bagasse-1.

11/00468 Effect of Cu on Ni nanoparticles used for the generation of carbon nanotubes by catalytic cracking of methane

González, I. *et al. Catalysis Today*, 2010, 149, (3–4), 352–357.

In this study, a simple method for the addition of Cu to unsupported nickel nanoparticles was used to investigate the promotion effect of copper during the nickel-catalysed decomposition of methane into carbon nanotubes. Bulk nickel and copper acetates were mixed by grinding the parent salts in a mortar, to obtain samples with selected Ni/Cu atomic ratios ($NiCu_{0.03}$, $NiCu_{0.07}$ and $NiCu_{0.16}$) that were decomposed *in situ* on methane streams using a thermogravimetric analyser. Weight increase was related quantitatively to the production of carbon nanotubes by catalytic cracking of methane, and the materials were complementary characterized *ex situ* by electron microscopy. The results suggest that copper most likely induces the disaggregation of nickel particles during the course of the catalytic cracking, but copper by itself was not effective to improve quantitatively the production of carbon nanotubes. In spite of very low methane conversions, good quality multiwalled carbon nanotubes were obtained and characterized by microscopy.

11/00469 High-yield charcoal production by two-step pyrolysis

Elyounssi, K. *et al. Journal of Analytical Applied Pyrolysis*, 2010, 87, (1), 138–143.

Low temperature isothermal pyrolysis of Thuja (*Tetraclinis articulata*) wood samples was carried out at atmospheric pressure. Changes in the fixed-carbon yield over time revealed the existence of two distinct phases. The first phase concerned hemicelluloses and cellulose decomposition. During that phase, char formation was promoted by low temperatures. At the end of that phase, the fixed-carbon yield was maximum. The value of the maximum was as great as that obtained under high-pressure pyrolysis and approached the theoretical value. During the second phase of the low temperature isothermal pyrolysis, the fixed-carbon yield decreased, showing a loss of the already existing carbon. But the rise in temperature immediately at the end of the first phase helped to preserve the value of the fixed-carbon yield reached at maximum. This novel temperature–time profile (low temperature pyrolysis followed by a rise in temperature) constitute a two-step pyrolysis of whole biomass which resolved the dilemma of increasing charcoal quality without excessively decreasing char yield.

11/00470 Influences of minerals transformation on the reactivity of high temperature char gasification

Bai, J. *et al. Fuel Processing Technology*, 2010, 91, (4), 404–409.

Two Chinese coals were used in this study and coal chars were prepared at different temperatures. High temperature gasification of coal chars with CO_2 was investigated in a bench scale fixed-bed reactor and the transformations of minerals from these two coals were also studied from 1100 to 1500 °C. Mineral matters produced at different temperature and ash generated after gasification were collected and analysed by XRD and FTIR. It was found that the iron oxides were only catalytic mineral matters existing at high temperature. And gasification behaviours above ash melting temperature were different for different mineral composition, especially the content and form of iron oxide, which not only accelerates the gasification reaction, but also reduces the influence caused by melting minerals.

11/00471 Thermogravimetric determination of coke from asphaltenes, resins and sediments and coking kinetics of heavy crude asphaltenes

Trejo, F. *et al. Catalysis Today*, 2010, 150, (3–4), 272–278.

Thermal analysis of asphaltenes and resins from heavy crude was carried out to understand the way in which they decompose to form coke. Sediments extracted from hydrotreated crude were also analysed. It was found that asphaltenes produced 47 wt% of coke, resins 9 wt% of coke, and sediments decompose quickly toward coke giving the highest yield (66 wt%). In the case of asphaltenes and resins a free-radicals-based mechanism is operating when labile points in alkyl chains are broken leading to condensation reactions. Thermal analysis of sediments obtained from hydrotreated crude revealed that they have high tendency to form coke. A non-isothermal technique using various heating rates was applied to study kinetics of asphaltene cracking toward coke formation. An iso-conversional method based on Friedman's procedure was used to calculate the reaction kinetic parameters from thermogravimetric analysis during asphaltene cracking and a set of activation energies and pre-exponential factor was obtained as the reaction progresses. Activation energy ranged from 29.2 to 52.4 kcal/mol.

02 LIQUID FUELS

Sources, properties, recovery

11/00472 A fracture sliding potential index for wellbore stability analysis

Younessi, A. and Rasouli, V. *International Journal of Rock Mechanics and Mining Sciences*, 2010, 47, (6), 927–939.

Sliding failure along the fractures intersecting a wellbore is one of the major wellbore instability mechanisms. This kind of failure is similar to the slope instabilities, a well-known phenomenon in mining and civil engineering. During drilling operations the drilling fluid can penetrate through fractures and lead to fracture reactivation and wellbore instability. The rock engineering systems (RES), initially introduced in the mining- and civil-related geomechanics problems, is an approach to analyse the interrelationship between the parameters affecting rock engineering activities. In this study, after discussing the sliding mechanism along a fracture in a wellbore during drilling, and identifying all the effective parameters, an interaction matrix is introduced to study the sliding failure mechanism. Thereafter, the interaction intensity and dominance of each parameter in the system is determined to classify these parameters. A systematic approach was used to determine the relative interactive intensity and value of each contributing parameter in the fracture sliding mechanism. As a result, an index is presented to estimate the fracture sliding potential. The results indicate the ability of this method to analyse wellbore instability due to fracture reactivation mechanism. This will assist in finding a better engineering action to mitigate or eliminate potential fracture sliding during drilling. The results show a good agreement with those obtained using Mohr–Coulomb failure analysis and field observations.

11/00473 Advances and challenges in explaining fuel spray impingement: how much of single droplet impact research is useful?
Moreira, A. L. N. *et al. Progress in Energy and Combustion Science*, 2010, 36, (5), 554–580.
The impingement of fuel spray onto interposed surfaces in an IC engine, equipped either with a direct or an indirect injection system, is a fundamental issue affecting mixture preparation prior to combustion and, therefore, also affecting engine performance and pollutant emissions. In this context, the development of fuel injection systems relies on accurate knowledge of the fluid dynamic and thermal processes occurring during spray/wall interaction. Injection systems however, are very complex and the background physics requires fundamental studies, performed at simplified flow geometries. In particular, the impact of individual droplets has been extensively used to describe the behaviour of spray impact and to predict its outcome, despite the known fact that a spray does not behave exactly as a summation of individual droplets; then, researchers incorporate all the governing parameters. The present paper offers a critical review of the investigations reported in the literature on spray-wall impact relevant to IC engines, in an attempt to address the rationale of describing spray-wall interactions based on the knowledge of single droplet impacts. Moreover, although the review was first aimed at fuel-spray impingement in IC engines, it also became relevant to provide a systematization of the current state of the art, which can be useful to the scientific community involved with droplet and spray impingement phenomena.

11/00474 An automation system for gas-lifted oil wells: model identification, control, and optimization
Camponogara, E. *et al. Journal of Petroleum Science and Engineering*, 2010, 70, (3–4), 157–167.
Smart fields technology advocates the use of a suite of skills, workflows, and technologies to drive efficiency gains while maximizing oil recovery from reservoirs. This paper contributes to smart fields technology by developing an automation system for integrated operation of gas-lift platforms, thereby bridging the gap between downhole devices (sensors, valves, and controllers) and surface facilities (operating policies, constraints, and faults). The components of the system are: (1) a module for identification of well-performance curves from downhole pressure measurements; (2) a control strategy for the pressure of the gas-lift manifold and a software sensor to indirectly measure the gas-mass flow-rate available for artificial lifting; and (3) an algorithm for optimal allocation of limited resources, such as the lift-gas rate, fluid handling capacities, and water-treatment processing capacity. The paper reports results from simulations performed with a prototype platform as a proof of concept.

11/00475 Chemical and morphological characterization of soot and soot precursors generated in an inverse diffusion flame with aromatic and aliphatic fuels
Santamaria, A. *et al. Combustion and Flame*, 2010, 157, (1), 33–42.
Knowledge of the chemical and physical structure of young soot and its precursors is very useful in understanding the paths leading to soot particle inception. This paper presents chemical and morphological characterization of the products generated in ethylene and benzene inverse diffusion flames (IDF) using different analytical techniques. The trend in the data indicates that the soot precursor material and soot particles generated in the benzene IDF have a higher degree of complexity than the samples obtained in the ethylene IDF, which is reflected by an increase in the aromaticity of the chloroform extracts observed by ^{1}H NMR and FT-IR, and shape and size of soot particles obtained by TEM and HR-TEM. It is important to highlight that the soot precursor material obtained at the lower positions in the ethylene IDF has a significant contribution of aliphatic groups, which play an important role in the particle inception and mass growth processes during the early stages of soot formation. However, these groups progressively disappear in the samples taken at higher positions in the flame, due to thermal decomposition processes.

11/00476 Comparison of correlations to predict hydrotreating product properties during hydrotreating of heavy oil
Martíne, J. *et al. Catalysis Today*, 2010, 150, (3–4), 300–307.
Eighteen correlations taken from the literature developed for predicting the properties and other process parameters during hydrotreating of petroleum fractions were tested with experimental information obtained at different conditions (type of feed, reactor and catalyst as well as reaction conditions) from which they were derived. First, the original values of parameters of each correlation were used to reproduce the experimental data, finding that most of them failed to do so. Secondly, the values of all parameters were optimized and predictions notoriously improved, but some correlations still exhibited difficulties. Finally, an attempt to correlate parameters with feedstock properties was made. It was found that the polynomial type showed the best prediction accuracy in general. The exponential equation also showed good prediction capability and good correlation between its parameters and feedstock properties.

11/00477 Elastic effects on Rayleigh-Bénard convection in liquids with temperature-dependent viscosity
Sekhar, G. N. and Jayalatha, G. *International Journal of Thermal Sciences*, 2010, 49, (1), 67–75.
A linear stability analysis of convection in viscoelastic liquids with temperature-dependent viscosity is studied using normal modes and Galerkin method. Stationary convection is shown to be the preferred mode of instability when the ratio of strain retardation parameter to stress relaxation parameter is greater than unity. When the ratio is less than unity then the possibility of oscillatory convection is shown to arise. Oscillatory convection is studied numerically for Rivlin-Ericksen, Maxwell and Jeffreys liquids by considering free-free, rigid-rigid and rigid-free isothermal/adiabatic boundaries. The effect of variable viscosity parameter is shown to destabilize the system. The problem reveals the stabilizing nature of strain retardation parameter and destabilizing nature of stress relaxation parameter, on the onset of convection. The Maxwell liquids are found to be more unstable than the one subscribing to Jeffreys description whereas the Rivlin-Ericksen liquid is comparatively more stable. Free-free adiabatic boundary combination is found to give rise to a most unstable system, whereas the rigid isothermal rigid adiabatic combination gives rise to a most stable system. The problem has applications in non-isothermal systems having viscoelastic liquids as working media.

11/00478 Electrical resistance tomography for characterisation of physical stability in liquid compositions
Kowalski, A. *et al. Chemical Engineering Journal*, 2010, 158, (1), 69–77.
The paper describes experiments to investigate the feasibility of using electrical tomography for early characterization of physical stability in selected products. The Manchester LCT tomograph has been applied to an eight-plane sensor hosted in a 1-litre vessel. Measurements have been taken over periods up to 76 h. Tomographic measurements and reconstructed images are consistent with visual observations associated with experiments that readily generate a distinct visible 'separated layer'. Observed diurnal excursions in the measured voltages have been investigated and related to changes in temperature. Later experiments have been performed in a temperature-controlled environment. Conductivity changes have been extracted from the reconstructed images for selected pixels. These reveal behaviour which is indicative of instability prior to visually discernible effects.

11/00479 Evaluation of co-volume mixing rules for bitumen liquid density and bubble pressure estimation
McFarlane, R. A. *et al. Fluid Phase Equilibria*, 2010, 293, (1), 87–100.
The Peng–Robinson cubic equation of state (CEOS) is widely used to predict thermodynamic properties of pure fluids and mixtures. The usual implementation of this CEOS requires critical properties of each pure component and combining rules for mixtures. Determining critical properties for components of heavy asymmetric mixtures such as bitumen is a challenge due to thermolysis at elevated temperatures. Group contribution methods were applied for the determination of critical properties of molecular representations developed by Sheremata for Athabasca vacuum tower bottoms (VTB). In contrast to other group contribution methods evaluated, the Marrero–Gani group contribution method yielded estimated critical properties with realistic, non-negative values, followed more consistent trends with molar mass and yielded normal boiling points consistent with high temperature simulated distillation data. Application of classical mixing rules to a heavy asymmetric mixture such as bitumen yields saturated liquid density and bubble pressure estimates in qualitative agreement with experimental data. However, the errors are too large for engineering calculations. In this work, new composite mixing rules for computing co-volumes of asymmetric mixtures are developed and evaluated. For example, composite mixing rules give improved bubble point predictions for the binary mixture ethane + n-tetratetracontane. For VTB and VTB + decane mixtures the new composite mixing rules showed encouraging results in predicting bubble point pressures and liquid phase densities.

11/00480 High performance sorbents for diesel oil desulfurization
Hernandez, S. P. *et al. Chemical Engineering Science*, 2010, 65, (1), 603–609.
Sorbents with different Ni loading supported on silica–alumina (SiAl) and activated carbon were synthesized and tested for removal of sulfur compounds from a model diesel oil, containing nearly 250 ppmw S as benzothiophene (BT), dibenzothiophene (DBT) and 4,6-dimethyldibenzothiophene (4,6-DMDBT). A state-of-art commercial Ni-based sorbent and two Norit activated carbons were also tested for comparison. Moreover, the influence on sorbents uptake capacity of the presence of aromatics in amounts representative of real diesel oils

was studied. Both commercial and home-made materials performed worse in presence of aromatic compounds. Probably, the latter competed with the refractory sulfur compounds (DBT and 4,6-DMDBT) in the adsorption on active sites. As a first important result of the investigation the sorbents carrying 45% and 30% of Ni on SiAl showed a breakthrough uptake capacity of nearly, respectively, 2 and 2.6 times higher than commercial sorbent as a consequence of their higher Ni dispersion and surface area. Moreover, activated carbons and the sample with 28%Ni on activated carbon showed an even higher breakthrough uptake capacities. In particular, the deposition of nickel on activated carbon is an innovative approach which takes advantage of the selectivity of Ni towards S-species and the high adsorptive capacity of activated carbon support.

11/00481 Molecular reconstruction of heavy petroleum residue fractions

Verstraete, J. J. *et al. Chemical Engineering Science*, 2010, 65, (1), 304–312.

Molecular reconstruction techniques are methods that allow the creation of mixtures of molecules from partial analytical data. In this article, a two-step reconstruction algorithm is presented. The first step, called 'stochastic reconstruction' step, assumes that oil mixtures can be described by distributions of structural blocks. The choice of the blocks and distributions is based on expert knowledge. The transformation from a set of distributions into a mixture of molecules is obtained by Monte–Carlo sampling, while a genetic algorithm adjusts the parametric distributions. The second step, termed 'reconstruction by entropy maximization', improves the representativeness of the set of constructed molecules by adjusting their molar fractions. The estimation of these molar fractions is carried out by maximizing an information entropy criterion under linear constraints. The two-step reconstruction algorithm allows to rebuild mixtures that resemble the petroleum fractions more closely than the approaches used previously. To illustrate the approach, the technique is applied to petroleum vacuum residue fractions.

11/00482 Oil shale pyrolysis kinetics and variable activation energy principle

Al-Ayed, O. S. *et al. Applied Energy*, 2010, 87, (4), 1269–1272.

A modified first order kinetic equation with variable activation energy is employed to model the total weight loss of Ellajjun oil shale samples. Fixed bed retort with 400 g of oil shale sample size is used in this study in 350–550 °C temperature range. Variable heating rate, h, in the range 2.6–5 °C min^{-1} are tested. Activation energy was allowed to vary as a function of oil shale conversion. The value of the activation energy increased from 98 to 120 kJ mol^{-1} while the corresponding frequency factor changed from 9.51×10^5 to 1.16×10^6. Fischer assay analysis of the studied samples indicated 12.2 wt% oil content. The oil shale decomposition ranged from 3.2% to 28.0%. The obtained kinetic data are modelled using variable heating rate, pyrolysis temperature and variable activation energy principle in a nitrogen sweeping medium. Good fit to the obtained experimental data is achieved.

11/00483 Production and fuel properties of fast pyrolysis oil/bio-diesel blends

Garcia-Perez, M. *et al. Fuel Processing Technology*, 2010, 91, (3), 296–305.

This paper describes the production and fuel properties of fast pyrolysis oil/biodiesel blends. The bio-oils used in this study were produced from the fast pyrolysis of woody biomasses, oil mallee and pine. The biodiesel used was derived from canola vegetable oil. The conditions used to prepare the bio-oil/biodiesel blends, as well as some of the fuel properties of the resulting biodiesel rich phase, are reported. The experimental results show that the solubility of fast pyrolysis oils in biodiesel is not as high as was previously reported for decanted oils obtained by Auger pyrolysis. The carboxylic acids, monophenols, furans and lignin-derived oligomers were the compounds most soluble in biodiesel, while the sugars, on the other hand, showed poor solubility. Although the presence of phenols enhances the oxidation stability of the biodiesel rich phases, other fuel properties deteriorate. For example, the content of solid residues increased primarily because of the solubilization of lignin-derived oligomers, which were quantified by UV-fluorescence. Concentrations as high as 3.5 mass% of these compounds were observed in the biodiesel-rich phase. The solubility of bio-oil in biodiesel was enhanced by using ethyl acetate/biodiesel blends. Some fuel properties of the biodiesel-rich phase, after the removal of ethyl acetate, are reported.

11/00484 REE geochemistry of marine oil shale from the Changshe Mountain area, northern Tibet, China

Fu, X. *et al. International Journal of Coal Geology*, 2010, 81, (3), 191–199.

The Shengli River–Changshe Mountain oil shale zone, located in the North Qiangtang depression, northern Tibet plateau, represents a potentially large marine oil shale resource in China. The contents and distribution patterns of rare earth elements (REEs) in selected oil shale and micritic limestone samples from the Changshe mountain area were studied by inductively-coupled plasma mass spectrometer (ICP-MS). Analysed oil shale samples from the Changshe Mountain area are characterized by high total organic carbon (TOC) contents (7.02–16.32%) and ash yields (53.22–82.12%) with shale oil contents from 3.85% to 11.76%. The total rare earth element (ΣREE) contents in oil shale samples are 68.19 μg/g, close to those of US coals, and higher than those of micritic limestone samples (37.69 μg/g) from the Changshe Mountain area, but lower than those of world-wide black shales, common Chinese coals, and North American Shale Composite. There are two types, A and B, of distribution patterns of REEs in the Changshe Mountain oil shale samples. Type A shows negligible Ce anomalies (0.97–1.01), with slightly higher ΣREE concentrations (36.87–118.38 μg/g) and LREE/HREE (6.79–10.74) and $(La/Yb)_n$ (6.68–8.36) ratios, whereas type B exhibits a slightly negative Ce anomaly (0.84–0.88), with slightly lower ΣREE concentrations (13.73–15.31 μg/g) and LREE/HREE (5.54–6.34) and $(La/Yb)_n$ (5.03–6.65) ratios. Both types A and B oil shales are characterized by distinctly sloping LREE trends ($La_n/Sm_n = 3.60–5.44$) accompanied by flat HREE trends, with distinct Eu negative anomalies (0.51–0.69). The vertical variations of ΣREE contents are similar to those of ash, Si, Al, K, Na, Ti and Fe, and show a negative correlation with organic sulfur and organic carbon, indicating that the REE contents in oil shale seams are mainly controlled by land-derived detritus.

Transport, refining, quality, storage

11/00485 A batch reactor study of the effect of deasphalting on hydrotreating of heavy oil

Sámano, V. *et al. Catalysis Today*, 2010, 150, (3–4), 264–271.

The effect of deasphalting of heavy oil with different degrees of asphaltenes precipitation on catalytic hydrotreating is reported in this work. Deasphalted oils were obtained in a pressurized vessel using n-heptane and n-pentane as solvents. Various samples with different amounts of asphaltenes were prepared by varying precipitation conditions. Hydrotreating of deasphalted oils was conducted with a commercial NiMo catalyst in a batch reactor at the following reaction conditions: hydrogen pressure of 100 kg/cm^2, temperature of 400 °C, stirring rate of 750 rpm and reaction time of 4 h. The heavy oil, the deasphalted oils and the hydrotreated products were characterized by sulfur, metals (Ni, V), asphaltene contents, and API gravity. Metals and carbon contents as well as textural properties and X-ray diffraction were also determined on fresh, spent and regenerated catalysts.

11/00486 Catalytic hydro desulphurization study of heavy petroleum residue through in situ generated hydrogen

Shakirullah, M. *et al. Energy Conversion and Management*, 2010, 51, (5), 998–1003.

Hydrodesulfurization of heavy residue was carried out using various catalysts in the presence of co-reactants as the internal sources of hydrogen. Reactions were carried out in a micro autoclave at 320 °C and 10 kg f/cm^2 pressure inert atmosphere of N_2 for 3 h reaction time. Tetralin, propane, methanol, ethylene glycol and formic acid were separately used as co-reactants as hydrogen donors. Among the solvents studied, methanol gave the highest hydrodesulfurization yield (52%). The reaction was then carried out in the presence of various catalysts to view the influence of each individual catalyst on the desulfurization yield under the same conditions of pressure and temperature. The catalysts used were Mo-Montmorillonite, Co-Montmorillonite, nickel oxide (NiO), cadmium oxide (CdO), Zn-ZSM5, kaolin and montmorillonite clays. The results show that all the catalysts exhibited desulfurization activity. In case of Mo-Montmorillonite and Co-Montmorillonite charges, the desulfurization yields of 63% and 46% were obtained, respectively. NiO, CdO, Zn-ZSM5, kaolin and montmorillonite clays gave desulfurization yields of 54%, 50%, 56%, 20% and 36%, respectively. The desulfurization activities of Mo-Montmorillonite and Co-Montmorillonite were compared with other catalysts used. The results show that Mo-Montmorillonite gave the highest hydrodesulfurization yield. FTIR studies also confirmed the hydrodesulfurization efficiency of the Mo-Montmorillonite.

11/00487 Complementary imaging of oil recovery mechanisms in fractured reservoirs

Ersland, G. *et al. Chemical Engineering Journal*, 2010, 158, (1), 32–38.

Complementary imaging techniques used to study enhanced oil recovery (EOR) processes in fractured oil reservoirs have provided new and improved fundamental understanding of how oil recovery is affected by fractures. The combination of two imaging techniques such as magnetic resonance imaging (MRI) and nuclear tracer imaging (NTI) enables a complementary investigation on materials and

processes, where large-scale (metres) phenomena are controlled by small scale (micrometres) heterogeneities. MRI provides high spatial resolution and fast data acquisition necessary to capture the processes that occur inside fractures less than 1 mm wide, while NTI provides information on macro-scale saturation distribution in larger fractured systems. The oil recovery mechanisms involved with waterflooding fractured chalk blocks were found to be dependent on the wettability of the chalk, as the wettability had great impact on the fracture/matrix hydrocarbon exchange. The MRI images of oil saturation development inside the fractures clearly revealed two distinct transport mechanisms for the wetting phase across the fracture at several wettability conditions, and provided new and detailed information on fluid fracture crossing previously observed in block scale experiments investigated by NTI. The ability to obtain rapid (seconds) one-dimensional saturation profiles, high spatial resolution two-dimensional images (sagital, transverse and coronal) within minutes and detailed three-dimensional images within a couple of hours, makes MRI a powerful tool in studies of multiphase flow in fractured porous rocks, and provides excellent dynamic information of enhanced oil recovery efforts.

11/00488 Degradation of oilwell cement due to exposure to carbonated brine

Duguid, A. and Scherer, G. W. *International Journal of Greenhouse Gas Control*, 2010, 4, (3), 546–560.

The growing interest in geologic carbon sequestration has highlighted the need for more data on how well cements react to CO_2 exposure. This paper describes a series of experiments that was conducted to examine the effects of flowing carbonated brine on well cements. Class H cement pastes were exposed to the ranges of temperature (20–50 °C) and pH (2.4–5) characteristic of geosequestration conditions at a depth of about 1 km. The exposed cements and the reactor effluents were analysed using multiple techniques including optical microscopy, X-ray diffraction, EPMA, and ICP-OES. The results showed that if the solution was pre-equilibrated with calcium carbonate, as would be expected in a limestone formation, there was no detectable attack. However, under the pH and temperature conditions to be expected in a sandstone formation, the initial rate of attack was of the order of millimetres per month. The outer layers of the cements reacted under sandstone-like conditions were fully degraded based on the results of the XRD and EPMA analyses. Inside the degraded layers there was a calcium carbonate-rich layer, a layer depleted of calcium hydroxide, and an unreacted cement core. The rate of degradation of the cement in these experiments was controlled by the rate of dissolution of the calcium carbonate-rich layer, after its formation, and diffusion through the fully degraded layers.

11/00489 High-active hydrotreating catalysts for heavy petroleum feeds: intentional synthesis of CoMo sulfide particles with optimal localization on the support surface

Pashigreva, A. V. *et al. Catalysis Today*, 2010, 150, (3–4), 164–170.

The method for preparation of high-active catalysts for hydrotreating of vacuum gas oil is described. The method is based on selective incorporation of bimetal Co–Mo complexes into pores of Al_2O_3 exposed to all molecules of the feedstock. The composition, structure and morphology of the resulting surface bimetal sulfide particles are very close to the particles characteristic of the best modern hydrotreating catalysts. The obtained catalyst is very active to hydrotreating of vacuum gas oil and superior to the best of Russian industrial catalysts.

11/00490 Hydrocracking of petroleum vacuum distillate containing rapeseed oil: evaluation of diesel fuel

Šimáček, P. and Kubička, D. *Fuel*, 2010, 89, (7), 1508–1513.

Hydrocracking of pure petroleum vacuum distillate and the same fraction containing 5 wt% of rapeseed oil was carried out at 400 and 420 °C and under a hydrogen pressure of 18 MPa over commercial Ni–Mo catalyst. Reaction products were separated by distillation into kerosene, gas oil and the residue. Fuel properties of fractions suitable for diesel production were evaluated (gas oils and remixed blends of kerosene and gas oil). Gas oils obtained from co-processing showed very good fuel properties as the remixed distillates did. Gas oil obtained from co-processing at 420 °C showed also reasonable key low-temperature properties (cloud point: −23 °C, CFPP: −24 °C) similar to those of gas oil obtained from pure petroleum raw material processing.

11/00491 Hydrodesulfurization of diesel in a slurry reactor

Deng, Z. *et al. Chemical Engineering Science*, 2010, 65, (1), 480–486.

The need for the more complete removal of sulfur from fuels due to lower permitted sulfur content in gasoline and diesel is made difficult by the increased sulfur contents of crude oils. This work reports an experimental study on the hydrodesulfurization (HDS) of diesel in a slurry reactor. HDS of straight-run diesel using a $NiMoS/Al_2O_3$ catalyst was studied in a high-pressure autoclave for the following operating conditions: 4.8–23.1 wt% catalyst in the reactor, 320–360 °C, 3–5 MPa pressure, and 0.56–2.77 L/min hydrogen flow rate. It was found that the reaction rate was proportional to the catalyst amount and increased with temperature, pressure and hydrogen flow rate. The reaction kinetics for the HDS reaction in the slurry reactor was obtained. As compared with HDS in a fixed bed reactor, HDS in a slurry reactor is promising because of the uniform temperature profile, high catalyst efficiency, and online removal and addition of catalyst.

11/00492 Performance of a slurry bubble column reactor for Fischer–Tropsch synthesis: determination of optimum condition

Woo, K.-J. *et al. Fuel Processing Technology*, 2010, 91, (4), 434–439.

The CO conversion and selectivity to C_1+ and $C_{11}+$ wax products over Co/Al_2O_3 as well as $Ru/Co/Al_2O_3$ Fischer–Tropsch catalysts were investigated by varying reaction temperature (210–250 °C), system pressure (1.0–3.0 MPa), GHSV (1000–6000 L/kg/h), superficial gas velocity (1.7–13.6 cm/s) and slurry concentration (9.09–26.67 wt%) in a slurry bubble column reactor (0.05 m diameter × 1.5 m height) to determine the optimum operating conditions. Squalane or paraffin wax was used as initial liquid media. The overall CO conversion increased with increasing reaction temperature, system pressure and catalyst concentration. However, the local maximum CO conversion was exhibited at GHSV of 1500–2000 L/kg/h and superficial gas velocity of 3.4–5.0 cm/s. The CO conversion in the case of $Ru/Co/Al_2O_3$ was much higher and stable than that in the case of Co/Al_2O_3. The selectivity to $C_{11}+$ wax products increased slightly with increasing GHSV; on the other hand, it decreased with increasing reaction temperature, system pressure, and solid concentration in a slurry bubble column reactor. It could be concluded that the optimum operating conditions based on the yield of hydrocarbons and wax products were; U_G = 6.8–10 cm/s, Cs = 15 wt%, T = 220–230 °C, P = 2.0 MPa in a slurry bubble column reactor for Fischer–Tropsch synthesis.

11/00493 Reliability and risk evaluation of a port oil pipeline transportation system in variable operation conditions

Soszynska, J. *International Journal of Pressure Vessels and Piping*, 2010, 87, (2–3), 81–87.

The semi-Markov model of the system operation processes is proposed and its selected characteristics are determined. A system composed on multi-state components is considered and its reliability and risk characteristics are found. Next, the joint model of the system operation process and the system multi-state reliability is applied to the reliability and risk evaluation of the port oil pipeline transportation system. The pipeline system is described and its operation process unknown parameters are identified on the basis of real statistical data. The mean values of the pipeline system operation process unconditional sojourn times in particular operation states are found and applied to determining this process transient probabilities in these states. The piping different reliability structures in various its operation states are fixed and their conditional reliability functions on the basis of data coming from experts are approximately determined. Finally, after applying earlier estimated transient probabilities and system conditional reliability functions in particular operation states the unconditional reliability function, the mean values and standard deviations of the pipeline lifetimes in particular reliability states, risk function and the moment when the risk exceeds a critical value are found.

11/00494 V-Mo based catalysts for ODS of diesel fuel. Part II. Catalytic performance and stability after redox cycles

González-García, O. and Cedeño-Caero, L. *Catalysis Today*, 2010, 150, (3–4), 237–243.

Vanadium–molybdenum oxides supported on alumina were prepared by successive wet-impregnation, in order to evaluate their activity in oxidative desulfurization (ODS) of sulfur compounds prevailing in diesel fuel. The oxidation states and reducibility of the catalysts were studied by means of reduction–oxidation cycles of temperature programmed, and chemical-quantitative analyses by permanganometric and ferrometric titrations, for fresh as well as used catalysts. Redox cycles were performed, involving TPR analyses separated by an oxidation treatment (TPO), which were carried out consecutively before or after ODS-batch cycles. ODS tests were carried out comparing oxidant performance of tert-butyl hydroperoxide and H_2O_2. TPR of the catalysts makes possible to have vanadium-oxides with different degree of reduction, which were correlated with ODS activity. According to these results vanadium-oxide species with 12.9% of reduction showed higher ODS performance.

Economics, business, marketing, policy

11/00495 Do gasoline prices exhibit asymmetry? Not usually!

Douglas, C. C. *Energy Economics*, 2010, 32, (4), 918–925.

Previous studies have found evidence of asymmetric price adjustment in US retail gasoline prices in that gasoline prices rise more rapidly in response to a cost increase than fall in response to a cost decrease. By estimating a threshold cointegration model that allows for multiple regimes, sensitivity of this result to outlying observations can be tested. In contrast to previous studies, little evidence of asymmetry was found for the vast majority of observations and that the asymmetry is being driven by a small number of outlying observations.

11/00496 Gas to liquids: a technology for natural gas industrialization in Bolivia

Velasco, J. A. *et al. Journal of Natural Gas Science and Engineering*, 2010, 2, (5), 222–228.

Gas-to-liquids (GTL) technology converts natural gas, through Fischer–Tropsch synthesis, into liquid and ultra-clean hydrocarbons such as light oils, kerosene, naphtha, diesel, and wax. Bolivia has natural gas reserves that reach 48.7 trillion cubic feet and produces nearly 40.0 million cubic metres per day, from which, around 88% are exported to Brazil and Argentina. In spite of these considerable amounts of natural gas reserves and production facilities, the country experiences a shortage of diesel which cannot be solved using conventional refining processes due the light nature of its crude oil. Thus, the GTL process seems to be a promising solution for Bolivia's diesel problems, at the same time that its natural gas reserves could be monetized. Although GTL can be considered as a well proven and developed technology, there are several aspects along the main processing steps (synthesis gas generation, Fischer–Tropsch synthesis, and product upgrading) to be considered at the time of implementing a GTL plant. The aim of this paper is to give an overall view of some relevant issues related to GTL technology as an option for natural gas industrialization in Bolivia, and also to provide a landscape of Bolivian natural gas industry.

11/00497 High speed diesel consumption and economic growth in India

Ghosh, S. *Energy*, 2010, 35, (4), 1794–1798.

This study probes the long-term equilibrium relationship among high-speed diesel (HSD) consumption, real GDP and price of HSD in India using autoregressive distributed lag (ARDL) bounds testing approach of cointegration for the time span 1972–1973 to 2005–2006. Empirical results reveal that the series are cointegrated and long term income elasticity for HSD demand in India is 1.27 while that for short-run is 0.46. Both long-run and short-run price elasticities are found to be statistically insignificant. The study also establishes a short-run bi-directional causality between economic growth and HSD consumption and the existence of a long-run unidirectional causality running from economic growth to HSD consumption. Finally, a set of policy prescriptions have been suggested to reduce the consumption of HSD, which should have no adverse impact on economy in the long-run.

11/00498 OECD's refiners face future of refinery cuts

Anon., *Oil and Energy Trends*, 2010, 35, (8), 3–6.

The refinery sector is suffering as hydrocarbon consumption in OECD countries falls through high prices and low economic growth. This has resulted in reduced utilization rates within OECD refineries over the past 10 years and, with limited alternative markets, more of these refineries are now being put up for sale.

11/00499 Process intensification in the petrochemicals industry: drivers and hurdles for commercial implementation

Harmsen, J. *Chemical Engineering and Processing: Process Intensification*, 2010, 49, (1), 70–73.

The process intensification technologies, reactive distillation, dividing wall column distillation (DWC) and reverse flow reactors (RFR) have been implemented at commercial scale in the petrochemical industry each more than 100 times. These technologies have been analysed with four drivers for innovation in the chemical process industry: feedstock cost reduction, capital expenditure reduction, energy reduction and safety risk reduction and with four hurdles for innovation: risk of failure by combining novel aspects, scale-up knowledge uncertainty, equipment unreliability and higher safety, health, environmental risks compared to conventional technologies. The analysis shows that reactive distillation, DWC and RFR all have significant capital cost reduction over conventional technologies and the first two also have energy reductions, while all hurdles for innovation are low. The preliminary conclusion is that process intensification technologies will probably be rapidly implemented in commercial scale operation when at least one of the mentioned drivers is existent and when all mentioned hurdles are low.

11/00500 Quantifying the impact of exogenous non-economic factors on UK transport oil demand

Broadstock, D. C. and Hunt, L. C. *Energy Policy*, 2010, 38, (3), 1559–1565.

This paper attempts to quantify the impact of exogenous non-economic factors on UK transport oil demand (in addition to income, price, and fuel efficiency) by estimating the demand relationship for oil transport for 1960–2007 using the structural time series model. From this, the relative impact on UK transport oil demand from income, price, and efficiency are quantified. Moreover, the relative impact of the non-economic factors is also quantified, based on the premise that the estimated stochastic trend represents behavioural responses to changes in socio-economic factors and changes in lifestyles and attitudes. The estimated elasticities for income, price and efficiency are 0.6, −0.1, and −0.3, respectively, and it is shown that for efficiency and price the overall contribution is relatively small, whereas the contribution from income and non-economic factors is relatively large. This has important implications for policy makers keen to reduce transport oil consumption and associated emissions, but not willing to reduce the trend rate of economic growth. Taxes and improved efficiency only have a limited impact; hence, a major thrust of policy should perhaps be on educating and informing consumers to persuade them to change their lifestyle and attitudes and thus reduce their consumption through the non-economic instruments route.

11/00501 The paradox of oil reserve forecasts: the political implications of predicting oil reserves and oil consumption

Balaban, O. and Tsatskin, A. *Energy Policy*, 2010, 38, (3), 1340–1344.

In the light of the outstanding importance of hydrocarbons for global energy, the controversy over peak oil has become both pressing and emotionally charged. Two conflicting parties – alarmists and optimists – hold irreconcilable positions. The shaping of the future energy policy is presently based on modelling results and geological considerations only. The authors show that the existing predictions of the energy crisis are increasingly mixed-up with value-judgments. The value analysis of those forecasts suggest that at least part of the estimations are implicit reflections of predictors' ends and values, and do not demonstrate a real ability to anticipate future conditions. Paradoxically, the question of oil reserves depletion is better understood when predictions are viewed as an instrument to impose the predictors' values and intervene in the currently bustling oil market. The intervention in the oil prices may occur in either direction becoming a tool to justify values rather than an instrument for the acquisition of knowledge.

11/00502 The peak of the oil age – analyzing the world oil production reference scenario in World Energy Outlook 2008

Aleklett, K. *et al. Energy Policy*, 2010, 38, (3), 1398–1414.

The assessment of future global oil production presented in the IEA's World Energy Outlook 2008 is divided into six fractions; four relate to crude oil, one to non-conventional oil, and the final fraction is natural-gas-liquids (NGL). Using the production parameter, depletion-rate-of-recoverable-resources, the authors have analysed the four crude oil fractions and found that the 75 Mb/d of crude oil production forecast for year 2030 appears significantly overstated, and is more likely to be in the region of 55 Mb/d. Moreover, analysis of the other fractions strongly suggests lower than expected production levels. In total, the analysis points to a world oil supply in 2030 of 75 Mb/d, some 26 Mb/d lower than the IEA predicts. The connection between economic growth and energy use is fundamental in the IEA's present modelling approach. Since the forecast sees little chance of a significant increase in global oil production, the findings suggest that the 'policy makers, investors and end users' to whom WEO 2008 is addressed should rethink their future plans for economic growth. The fact that global oil production has very probably passed its maximum implies that we have reached the oeak of the oil age.

Derived liquid fuels

11/00503 Characterization of asphaltenes precipitated with three light alkanes under different experimental conditions

Luo, P. *et al. Fluid Phase Equilibria*, 2010, 291, (2), 103–110.

Asphaltene precipitation plays an important role in both oil production and refining processes. In this paper, asphaltenes are precipitated from a heavy oil sample under different experimental conditions by using three different light alkanes, i.e. propane, *n*-pentane, and *n*-heptane. A variety of analytical techniques are applied to characterize the precipitated asphaltenes and deasphalted heavy oil (i.e. maltenes),

such as the density and viscosity measurements, vapour-pressure osmometry, freezing-point osmometry, scanning electron microscope imaging, nuclear magnetic resonance measurement, and simulated distillation for compositional analysis. It is found that the yields and properties of the precipitated asphaltenes and remaining maltenes strongly depend on the specific precipitant tested and the liquid precipitant-to-oil volume ratio used. The asphaltene yield decreases as the carbon number of an alkane increases, while it increases monotonically and finally reaches a plateau if the liquid precipitant-to-oil volume ratio increases up to 20–40 for *n*-pentane and *n*-heptane, respectively. As a result, *n*-heptane-precipitated asphaltenes (C_7-asphaltenes) have the highest molecular weight and aromaticity among the three kinds of precipitated asphaltenes. C_7-asphaltenes are bright and black particles, whereas *n*-pentane-precipitated asphaltenes (C_5-asphaltenes) are dull and brown powders. Propane-precipitated asphaltenes (C_3-asphaltenes) together with some amount of co-precipitated resins are found to be highly viscous and semi-solid like immediately after the flashed-off process but become more and more liquid-like afterward. Compositional analysis results of the original heavy crude oil and three different maltenes indicate that the carbon numbers of most precipitated asphaltenes are higher than C_{50}.

11/00504 Coal liquefaction technologies – development in China and challenges in chemical reaction engineering

Liu, Z. *et al. Chemical Engineering Science*, 2010, 65, (1), 12–17.

With rapidly increasing demand in liquid transportation fuels, limited and unevenly distributed petroleum resources, and volatile petroleum prices, coal liquefaction technologies have once again received the world's attention. China has actively pursued the research and development of coal liquefaction technologies in the past decade and is deploying the first and the largest direct coal liquefaction plant since the 1940s and the largest indirect coal liquefaction plants after Sasol in South Africa. This paper analyses the historical developments of coal liquefaction technologies from a scientific point of view, presents recent developments of the technologies in China, and identifies the challenges of the technologies that are needed to result in successful industrial application.

11/00505 Enhancement of methanol production in a novel cascading fluidized-bed hydrogen permselective membrane methanol reactor

Rahimpour, M. R. *et al. Chemical Engineering Journal*, 2010, 157, (2–3), 520–529.

In this work, a novel cascading fluidized-bed hydrogen permselective membrane methanol reactor (CFBMMR) concept has been proposed. In the first catalyst bed, the synthesis gas is partly converted to methanol in water-cooled reactor which is a fluidized bed. In the second bed which is a membrane assisted fluidized-bed reactor, the reaction heat is used to preheat the feed gas to the first bed. This reactor configuration solves some observed drawbacks of new conventional dual-type methanol reactor even better than fluidized-bed membrane dual-type methanol reactor (FBMDMR). The two-phase theory in bubbling regime of fluidization is used to model and simulate the proposed reactor. The proposed model has been used to compare the performance of a CFBMMR with industrial dual-type methanol reactor (IDMR) and FBMDMR. This comparison shows that fluidizing catalyst bed in the water-cooled reactor caused a favourable temperature profile along the CFBMMR. Additionally, the simulation results represent 3.94% and 9.53% enhancement in the yield of methanol production in comparison with FBMDMR and IDMR respectively.

11/00506 Experimental investigation and modeling of steam cracking of Fischer–Tropsch naphtha for light olefins

Wang, F. *et al. Chemical Engineering and Processing: Process Intensification*, 2010, 49, (1), 51–58.

The characteristics of product distribution and the kinetic model for predicting the yields of the major products from steam cracking of Fischer–Tropsch (F–T) naphtha have been investigated in a pilot plant under various conditions. An analysis of the experimental data suggests that the naphtha produced via the low-temperature slurry-phase F–T process is an excellent feedstock for the production of light olefins, especially ethylene. For steam cracking of two F–T naphthas studied, ethylene is the primary product varying from 36.89 to 41.83 wt%, and the total yield of valuable light olefins (C_2H_4, C_3H_6 and 1,3-C_4H_6) is not less than 60.34 wt% under the conditions estimated. The experimental product distributions could be satisfactorily predicted by use of a detailed molecular reaction scheme which consists of a first-order primary reaction and 37 secondary reactions.

11/00507 Gas condensate characterization from chromatogram areas and retention times

Folsta, K. C. B. M. *et al. Fluid Phase Equilibria*, 2010, 292, (1–2), 87–95.

In a routine thermodynamic modelling performance test, mean values for pseudocomponents' critical temperatures and pressures up to C_{40} are re-estimated for Brazilian gas condensate fields based on gas chromatography areas and retention times. Once the fraction's n-paraffin is located by its retention time in the chromatogram, the areas of all other peaks after the previous n-paraffin are computed to make up a fake non-paraffinic compound of the fraction, whose mean boiling temperature is related to its area-weighted retention time. Using a traditional three-parameter relationship among density, molecular weight and boiling temperature, these parameters, together with the molecular weight and density of the non-paraffinic compound, are estimated for each fraction up to C_{40}, and used for the other samples to provide local single carbon number tables. The performance of such tables is compared with the original one proposed in the literature in predicting experimental PVT data using Peng–Robinson EOS in commercial simulators. Results were not improved as expected, suggesting that gas condensate thermodynamic properties are very sensitive to heavy ends mole fraction provided by gas chromatography. Rather than introducing new concepts on gas condensate thermodynamic modelling, this paper intends to provide new experimental data (and also some simple treatment on them), checking some day-by-day tools to confirm that EOS tuning strategies for gas condensate fluids remain unavoidable.

11/00508 In-depth modeling of gas oil hydrotreating: from feedstock reconstruction to reactor stability analysis

López García, C. *et al. Catalysis Today*, 2010, 150, (3–4), 279–299.

The increasing demand for clean fuels requires improving existing hydrotreating (HDT) technologies through comprehensive studies of these complex reactive systems. This work presents a modelling approach of diesel cut hydrotreating which ranges from the chemical characterization of gas oil feeds, over the HDT kinetic modelling and the thermal stability analysis of the reactor. In this approach, a 'statistical reconstruction' method was developed to represent the composition by chemical family and by carbon number of different gas oils starting from a set of global analyses. A kinetic model based on a Langmuir–Hinshelwood representation was developed to determine the most adequate operating conditions to attain on-road diesel specifications, including sulfur levels as low as 10 wt ppm. Finally, since hydrotreating reactions are highly exothermic, the thermal stability analysis of a HDT reactor is also presented. This analysis consists of determining *a priori* whether the reactive system is thermally stable and therefore predicting if runaway will occur. For the latter, a complete dynamic model of the reactor was developed and used to assess the thermal runaway analysis by the perturbations theory.

11/00509 Quantitative study on cross-linking reactions of oxygen groups during liquefaction of lignite by a new model system

Wang, Z. *et al. Fuel Processing Technology*, 2010, 91, (4), 410–413.

Cross-linking reactions (CLR) of oxygen groups during liquefaction of lignite were quantitatively studied by a new model system. Chinese Yitai lignitewas first oxidized by nitric acid at 70 °C and about 98% of the oxidized sample could be dissolved in tetrahydrofuran (THF) at room temperature. Then benzyl alcohol, $PhCH_2OH$, as a model compound was added into the oxidized coal, also acted as solvent in the subsequent liquefaction. Temperature-programmed reactions at liquefaction conditions under hydrogen atmosphere were performed to evaluate the CLR by quantitative analysis of THF-insoluble solid products (THFI) after reaction. Extensive CLR were observed even under high pressure of H_2 at 200–400 °C, and more than 51.7% and 81.2% of the THFS fraction was converted into the THFI at 300 °C with tetralin and benzyl alcohol as solvent, respectively. The THFI fraction was almost solely caused by the CLR, which makes it possible to quantitatively study the CLR by analysing the amount of the cross-linked solid products (CSP). The pyrolysis behaviours of CSP and oxidized coal were examined by TG. Other model compounds containing oxygen-functional groups (alcohol, phenol, carboxyl, carbonyl and ether groups) can also be used in this model system to study CLR of oxygen groups in low-rank coals.

11/00510 Study of induction period over K_2CO_3/MoS_2 catalyst for higher alcohols synthesis

Xiao, H. *et al. Fuel Processing Technology*, 2010, 91, (4), 383–387.

The K_2CO_3/MoS_2 catalyst for higher alcohols synthesis with synthesis gas as feedstock was prepared. The catalyst was characterized by TPR, *in situ* XPS, XRD and SEM. Effects of pretreatment with H_2, CO or synthesis gas on activity and selectivity of the catalyst were investigated. Results showed that there was a remarkable induction period about 180 h at the initial reaction stage for the untreated catalyst. The catalytic performances for alcohols synthesis changed notably during the induction period. The induction period was confirmed to be resulted primarily from the sulfur losing and K element dispersion on the surface of ADM catalysts. Pretreatment of the catalyst could remarkably shorten the time of induction period as

well as promote the catalytic activity. Furthermore, the higher alcohols (C_2 + OH) content in the liquid products were enhanced after the catalyst pretreated by CO or synthesis gas which could be ascribed to the increasing of Mo^{4+} content on the surface of the catalyst.

11/00511 ZSM-5 supported iron catalysts for Fischer–Tropsch production of light olefin

Kang, S.-H. *et al. Fuel Processing Technology*, 2010, 91, (4), 399–403.
Fischer–Tropsch synthesis (FTS) for olefin production from syngas was studied on Fe–Cu–K catalysts supported on ZSM-5 with three different Si/Al ratios. The catalysts were prepared by slurry-impregnation method of metallic components, and were characterized by BET surface area, XRD, hydrogen TPR and ammonia TPD. Fe–Cu–K/ZSM-5 catalyst with a low Si/Al ratio (25) is found to be superior to the other catalysts in terms of better C_2–C_4 selectivity in the FTS products and higher olefin/(olefin + paraffin) ratio in C_2–C_4 because of the facile formation of iron carbide during FTS reaction and also due to a larger number of weak acidic sites that are present in these catalysts.

03 GASEOUS FUELS

Sources, properties, recovery, treatment

11/00512 Ageing mechanisms on PdO_x-based catalysts for natural gas combustion in premixed burners

Specchia, S. *et al. Chemical Engineering Science*, 2010, 65, (1), 186–192.
The ageing effect induced by S-compounds over 2%Pd/CeO_2·2ZrO_2, 2%Pd/$LaMnO_3$·2ZrO_2 and 2%Pd/$BaCeO_3$·2ZrO_2 catalysts for CH_4 combustion was investigated; S-compounds are in fact added as odorants in the natural gas network for safety purposes. Pd-based catalysts were prepared by solution combustion synthesis (SCS), starting from metal nitrates/glycine mixtures. Basic characterization (XRD, BET, FESEM analysis), FT–IR studies and catalytic activity tests were performed on powders and after accelerated ageing carried out up to 2 weeks (hydrothermal treatment at 900 °C under a flow rate with typical domestic boiler exhaust gas composition, 9% CO_2, 18% H_2O, 2% O_2 in N_2, containing also 200 ppmv of SO_2 to emphasize any poisoning effect). Over fresh catalysts, IR analysis of CO adsorption evidenced the formation of highly dispersed Pd metal clusters and Pd ions. With ageing, 2%Pd/CeO_2·2ZrO_2 increased its CH_4 combustion half-conversion temperature (T_{50}, regarded as an index of catalytic activity) from 382 °C – recorded for fresh sample – to 421 °C, attained with the same sample aged two weeks. An unexpected improvement was found instead in the overall performance of 2%Pd/$LaMnO_3$·2ZrO_2 and 2%Pd/$BaCeO_3$·2ZrO_2: the T_{50} in fact lowered from 570 to 450 °C for the first one, and from 512 to 443 °C for the second one, after two weeks ageing. S-hydrothermal treatment provoked bulk and surface sulfates formation on all aged samples, with a concentration increasing with the exposure time. Prevailing ageing mechanisms seemed to be Pd metallic clusters coalescence, detected over the Ce–Zr system, and surface-bulk sulfates formation, the latter destroying the initial crystallographic structure. In 2%Pd/$LaMnO_3$·ZrO_2 and 2%Pd/$BaCeO_3$·ZrO_2 powders the amount of the perovskite phase strongly decreased during ageing, in favour of the formation of bulk sulfate and of oxides.

11/00513 Assessing the permafrost temperature and thickness conditions favorable for the occurrence of gas hydrate in the Qinghai–Tibet Plateau

Wu, Q. *et al. Energy Conversion and Management*, 2010, 51, (4), 783–787.
Permafrost accounts for about 52% of the total area of the Qinghai–Tibet Plateau, and the permafrost area is about 140×10^4 km^2. The mean annual ground temperature of permafrost ranges from −0.1 to −5 °C, and lower than −5 °C at extreme high-mountains. Permafrost thickness ranges from 10 to 139.4 m by borehole data, and more than 200 m by geothermal gradients. The permafrost geothermal gradient ranges from 1.1 °C/100 m to 8.0 °C/100 m with an average of 2.9 °C/100 m, and the geothermal gradient of the soil beneath permafrost is about 2.8–8.5 °C/100 m with an average of 6.0 °C/100 m in the Qinghai–Tibet Plateau. For a minimum of permafrost geothermal gradients of 1.1 °C/100 m, the areas of the potential occurrence of methane hydrate (sI) is approximately estimated to be about 27.5% of the total area of permafrost regions in the Qinghai–Tibet Plateau. For an average of permafrost geothermal gradients of 2.9 °C/100 m, the areas of the potential occurrence of methane hydrate (sI) is approximately estimated about 14% of the total area of permafrost regions in the Qinghai–Tibet Plateau. For the sII hydrate, the areas of the potential occurrence of sII hydrate are more than that of sI methane hydrate.

11/00514 Case study of estimating gas loss from a producing well blowout

Hsieh, B.-Z. *et al. Journal of Petroleum Science and Engineering*, 2010, 70, (3–4), 327–333.
The purpose of this study is to estimate gas loss from a production blowout of well K-140 in a gas field in Taiwan. Two approaches can be successfully used to estimate gas loss: (1) analysis of the p/z plot, based on the gas material balance equation, and (2) study of pressure history matching of reservoir simulation. In the analysis of the p/z plot, the gas loss from well K-140 is estimated by analysing the differences between the pressure prior and subsequent to blowout in the p/z plot. In the reservoir simulation study, two stages of pressure history matching are separately conducted using pressure data before and after the blowout. The first stage history match is for tuning the numerical model; the second stage history match is for estimating gas loss from the production blowout of well K-140. The gas loss estimated from the history match is 1.45×10^{10} SCF (4.11×10^8 SCM) which is very close to the 1.358×10^{10} SCF (3.85×10^8 SCM) estimated from analysis of the p/z plot.

11/00515 Intensification of steam reforming of natural gas: choosing combustible fuel and reforming catalyst

Stefanidis, G. D. and Vlachos, D. G. *Chemical Engineering Science*, 2010, 65, (1), 398–404.
The steam reforming of methane in a parallel plate microreactor, consisting of alternating channels carrying out catalytic combustion and reforming on opposite sides of a wall, is modelled with fundamental kinetics and a pseudo-2D reactor model. It is shown that at high fuel conversions, the choice of hydrocarbon combustible fuel is immaterial when suitable compositions are used so that the energy input is kept the same. On the other hand, direct comparison of Rh and Ni indicates that the choice of reforming catalyst is critical. Speed up of heat transfer via miniaturization is insufficient for process intensification; catalyst-intensification is also needed to avoid hot spots and enable compact devices for portable and distributed power generation.

11/00516 Modeling of non-catalytic partial oxidation of natural gas under conditions found in industrial reformers

Zhou, X. *et al. Chemical Engineering and Processing: Process Intensification*, 2010, 49, (1), 59–64.
Non-catalytic partial oxidation of natural gas/O_2/H_2O mixture at elevated pressures was simulated kinetically using Chemkin package incorporating detailed reaction mechanisms of methane oxidation. The dependence of reaction time was investigated as a function of inlet temperature, system pressure, and O_2/CH_4 ratio. The conversion to products was predicted to complete within a residence time of less than 0.1 ms at pressures greater than 30 atm and temperatures higher than 1450 K. A minimum O_2/CH_4 ratio of 0.64 was found necessary for a complete methane conversion at the conditions typical for the industrial reformer. The effect of O_2/H_2O in the feed gas was examined computationally, and the results suggested that adding H_2O in the feed gas could be a viable tool for adjusting the H_2/CO ratio in the products and for controlling the flame temperature. Formations of higher order hydrocarbons and soot, which may play important roles in the actual fuel-rich conversion environment, are not considered in the present study.

11/00517 Performance of a large capacity propane heat pump with low charge heat exchangers

Cavallini, A. *et al. International Journal of Refrigeration*, 2010, 33, (2), 242–250.
The experimental performance of a 100 kW heat pump using propane is presented. The charge minimization is a priority in the design of such a device and thus shell-and-tube heat exchangers using minichannels and providing low charge have been installed in the unit, along with conventional brazed plate heat exchangers, in order to compare different working configurations, both in terms of energy efficiency and refrigerant charge. The performance when using the minichannel condenser is here compared to the one obtained when using a brazed plate condenser and the influence of a minichannel internal heat exchanger on the performance of the equipment is measured and discussed. It is shown that a 100 kW heat pump without a liquid receiver could be run with around 3 kg of propane using a plate condenser and a plate evaporator. Using the minichannel condenser, around 0.8 kg reduction can be obtained with a negligible performance loss.

11/00518 Propagation and extinction of premixed C_5–C_{12} *n*-alkane flames

Ji, C. *et al. Combustion and Flame*, 2010, 157, (2), 277–287.

Laminar flame speeds and extinction strain rates of premixed C_5–C_{12}*n*-alkane flames were determined at atmospheric pressure and elevated unburned mixture temperatures, over a wide range of equivalence ratios. Experiments were performed in the counterflow configuration and flow velocities were measured using laser Doppler velocimetry. The laminar flame speeds were obtained using a non-linear extrapolation technique utilizing numerical simulations of the counterflow experiments with detailed descriptions of chemical kinetics and molecular transport. Compared to linearly extrapolated values, the laminar flame speeds obtained using non-linear extrapolations were found to be 1–4 cm/s lower depending on the equivalence ratio. It was determined that the laminar flame speeds of all *n*-alkane/air mixtures considered in this investigation are similar to each other and sensitive largely to the H_2/CO and C_1–C_4 hydrocarbon kinetics. Additionally, the resistance to extinction decreases as the fuel molecular weight increases. Simulations of the experiments were performed using the recently developed JetSurF 0.2 reaction model consisting of 194 species and 1459 reactions. The laminar flame speeds were predicted with good accuracy for all the *n*-alkane–air mixtures considered. The experimental extinction strain rates are well predicted by the model for fuel-lean mixtures. For stoichiometric and fuel-rich mixtures, the predicted extinction strain rates are approximately 10% lower than the experimental values. Insights into the physical and chemical processes that control the response of *n*-alkane flames are provided through detailed sensitivity analyses on both reaction rates and binary diffusion coefficients.

11/00519 Radial flow of yield-power-law fluids: numerical analysis, experimental study and the application for drilling fluid losses in fractured formations

Majidi, R. *et al*. *Journal of Petroleum Science and Engineering*, 2010, 70, (3–4), 334–343.

A theoretical solution for radial flow of yield-power-law (Herschel–Bulkley) fluids between two parallel disks is presented. The fundamental equations are based on momentum balance in radial coordinates. The solution encompasses the Newtonian, Bingham plastic and power-law fluids as special cases. The numerical solution has been compared with experimental data obtained from radial flow between two parallel disks. Upon application of mathematical simplifications, a closed form expression for pressure drop for radial flow of yield-power-law fluids is obtained and presented as an 'approximate analytical' solution. The validity of the approximate solution is examined versus numerical solution. The application of the approximate solution to the prediction of drilling fluid losses in fractured formations is discussed.

11/00520 Surface characterization of palladium–alumina sorbents for high-temperature capture of mercury and arsenic from fuel gas

Baltrus, J. P. *et al*. *Fuel*, 2010, 89, (6), 1323–1325.

Coal gasification with subsequent cleanup of the resulting fuel gas is a way to reduce the impact of mercury and arsenic in the environment during power generation and on downstream catalytic processes in chemical production. The interactions of mercury and arsenic with Pd/Al_2O_3 model thin film sorbents and Pd/Al_2O_3 powders have been studied to determine the relative affinities of palladium for mercury and arsenic, and how they are affected by temperature and the presence of hydrogen sulfide in the fuel gas. The implications of the results on strategies for capturing the toxic metals using a sorbent bed are discussed.

Transport, storage

11/00521 An integrated quantitative risk analysis method for natural gas pipeline network

Han, Z. H. *et al*. *Journal of Prevention in the Process Industries*, 2010, 23, (3), 428–436.

The natural gas industry is developing rapidly, and its accidents are threatening urban safety. Risk management through quantitative assessment has become an important way to improve the safety performance of the natural gas supply system. In this paper, an integrated quantitative risk analysis method for natural gas pipeline network is proposed. This method is composed of the probability assessment of accidents, the analysis of consequences and the evaluation of risk. It is noteworthy that the consequences analysed here include those of the outside and inside gas pipelines. The analysis of consequences of the outside pipelines focuses on the individual risk and societal risk caused by different accidents, while those of the inside pipelines concerns about the risk of the economic loss because of the pressure redistribution. Risk of a sample urban gas pipeline network is analysed to demonstrate the presented method. The results show that this presented integrated quantitative risk analysis method for natural gas pipeline network can be used in practical application.

11/00522 Analytical solution of transverse shear strain vibration of gas detonation loaded tube near second critical speed (shear group velocity)

Biglari, H. and Jafari, A. *International Journal of Pressure Vessels and Piping*, 2010, 87, (2–3), 117–125.

Analytical solution of transverse shear strain vibration of a tube caused by internal gaseous detonation near the second critical speed (shear group velocity) is not reported in the literature. It is performed based on a steady state model and first order shear deformation theories (model I and II) in this paper, and the results are verified through comparison with the finite element results reported in the literature. There are no known experimental ways of directly measuring dynamic transverse shear strain and only theoretical results and numerical data are available. The finite element method is very time consuming compared with the analytical solution. It is shown in this paper that the resonance phenomenon of the transverse shear strain vibration near the second critical speed can be predicted by steady state model and first order shear deformation theories. The first order shear deformation theory (model II) has a good agreement with finite element results in prediction of dynamic amplification factors and critical speeds.

11/00523 Cryosorption storage of gaseous hydrogen for vehicular application – a conceptual design

Ghosh, I. *et al*. *International Journal of Hydrogen Energy*, 2010, 35, (1), 161–168.

A conceptual design for the cryosorption storage of gaseous hydrogen in activated carbon for vehicular application has been presented. In this work, a novel concept for the storage/discharge of hydrogen has been proposed. This system ensures faster filling and gradual release of hydrogen on demand. These two features are important for making onboard hydrogen storage effective for small cars. Numerical models for adsorption and desorption half cycles are presented. Assuming that the pressurization and depressurization are occurring adiabatically, transient analysis has been done to critically study the effective hydrogen storage capacity of activated carbon. The amount of activated carbon required to store hydrogen for travelling a specific distance has been computed.

11/00524 Dimensionless lumped formulation for performance assessment of adsorbed natural gas storage

da Silva, W. M. J. and Sphaier, L. A. *Applied Energy*, 2010, 87, (5), 1572–1580.

Adsorbed natural gas (ANG) has been emerging as an attractive alternative to compressed natural gas or liquefied natural gas, on various circumstances. However, in spite of the advantages associated with ANG over other storage modes, there are some issues that need be properly addressed. One major problem is that the thermal effects associated with the sorption phenomena tend to diminish the storage capacity, thereby resulting in poorer performance. Hence, in order to design commercially viable storage vessels, the heat and mass transfer mechanisms that occur in these devices must be carefully understood and controlled. With the purpose of improving the understanding of mass and energy transport within ANG vessels, dimensionless groups associated with this problem have been developed in this study, resulting in an innovation to the ANG literature. Along with the dimensionless groups, a lumped-capacitance formulation has been also proposed. Although this type of formulation is limited compared to the multi-dimensional formulations present in the literature, its computational solution is remarkably faster. Numerical solution results using the proposed lumped formulation are compared with those of a previous study, suggesting that the simpler model can be applied to larger process times. The process of charging and discharging ANG vessels was then simulated employing the proposed formulation for different combinations of the developed dimensionless groups. In order to properly assess charge and discharge processes, a performance coefficient was employed. The results show that increasing the heat capacity ratio and dimensionless heat transfer coefficient tend to augment the performance coefficient, whereas an increase in the dimensionless heat of sorption worsens performance. The proposed normalization scheme is applicable to both multi-dimensional and spatially-lumped formulations, thereby facilitating the analysis of heat transfer enhancement in these storage vessels.

11/00525 Mechanistic modeling of pipeline leak detection at fixed inlet rate

Kam, S. I. *Journal of Petroleum Science and Engineering*, 2010, 70, (3–4), 145–156.

A leak from subsea pipelines has been a serious problem in deepwater operations because of its potential threat to surrounding marine environments, significant monetary loss from the delay of hydrocarbon production, and difficulty in detection and remedial processes. For the first time, this study shows how a leak in long horizontal subsea pipelines can be modelled mechanistically using pressure traverse calculations, and presents the results in a form of contour plots, with 'a

change in inlet pressure (ΔP_{in})' or 'a change in outlet flowrate (Δq_{tout})' induced by a leak in z axis as a function of leak opening size and longitudinal pipe location in the x- and y-axes. Beggs and Brill's correlations provided a means of deciphering complicated gas–oil two-phase flow mechanisms in pipelines. The calculated steady-state response of the system before and after the leak was investigated in terms of pressure gradient, flow rate, hold-up, and flowing fraction, which were validated and well agreed with results from a quasi-dynamic numerical simulation. The results showed that the outlet flowrate monitored at the receiving facilities (q_{tout}) could be a good indicator to detect a leak, while the pressure monitored at the inlet (P_{in}) was less reliable. The use of inlet pressure became more trustworthy with decreasing backpressure downstream (or increasing gas compressibility equivalently). The results also demonstrated that a leak is more easily detected if located further upstream with a larger opening size, and the presence of a compressible phase in pipelines makes leak detection more favourable leading to larger Δq_{tout}. The effects of gas–oil ratio of leaking fluids, gas compressibility, leak size, and leak coefficient were investigated, and the nature of transient behaviour between the two steady states, before and after the leak, was also examined.

11/00526 The accuracy and efficiency of a MATLAB-Simulink library for transient flow simulation of gas pipelines and networks

Behbahani-Nejad, M. and Bagheri, A. *Journal of Petroleum Science and Engineering*, 2010, 70, (3–4), 256–265.

An efficient transient flow simulation for gas pipelines and networks is proposed. The proposed transient flow simulation was based on the transfer function models and MATLAB-Simulink. The equivalent transfer functions of the non-linear governing equations were derived for different boundary conditions types. Next, a MATLAB-Simulink library was developed and proposed considering any boundary condition. To verify the accuracy and the computational efficiency of the proposed simulation, the results obtained are compared with those of the conventional finite difference schemes (such as total variation diminishing algorithms, method of lines, and other finite difference implicit and explicit schemes). The effect of the flow inertia was incorporated in this simulation. The accuracy and computational efficiency of the proposed method are discussed for several test cases. It is shown that the proposed simulation has a sufficient accuracy and it is computationally more efficient than the other methods.

Economics, business, marketing, policy

11/00527 Compact fluorescent lighting and residential natural gas consumption: testing for interactive effects

Brunner, E. J. *et al. Energy Policy*, 2010, 38, (3), 1288–1296.

Replacing incandescent light bulbs with compact fluorescents (CFLs) has traditionally been seen as a cost effective means of promoting energy conservation. Recently, however, the magnitude of energy savings associated with CFLs has been called into question. Specifically, recent findings suggest an 'interactive effect' associated with the replacement of incandescent light bulbs with CFLs in the residential sector. In this scenario, the reduced wattage of CFLs, relative to incandescent bulbs, generates less heat, which in turn, requires additional natural gas usage during the heating season. Engineering studies suggest the magnitude of the effect is significant in energy terms, which implies that the energy savings associated with CFLs may be significantly overstated. This study uses billing analysis to test for the presence of interactive effects. The analysis is based on a comprehensive dataset that includes monthly household electricity and natural gas usage, the number of CFL bulbs installed, the installation date, and a set of household characteristics. The results suggest that CFLs do indeed save electricity. However, there was no evidence to support the hypothesis that CFLs cause increased usage of natural gas.

11/00528 Economic analysis of hydrogen production through a bio-ethanol steam reforming process: sensitivity analyses and cost estimations

Song, H. and Ozkan, U. S. *International Journal of Hydrogen Energy*, 2010, 35, (1), 127–134.

In this study, the hydrogen selling price from ethanol steam reforming has been estimated for two different production scenarios in the USA, i.e. central production (150,000 kg H_2/day) and distributed (forecourt) production (1500 kg H_2/day), based on a process flowchart generated by Aspen Plus® including downstream purification steps and economic analysis model template published by the US Department of Energy (DOE). The effect of several processing parameters as well as catalyst properties on the hydrogen selling price has been evaluated. \$2.69/kg is estimated as the selling price for a central production process of 150,000 kg H_2/day and \$4.27/kg for a distributed hydrogen production process at a scale of 1500 kg H_2/day. Among the parameters investigated through sensitivity analyses, ethanol feedstock cost, catalyst cost, and catalytic performance are found to play a significant role on determining the final hydrogen selling price.

11/00529 Estimating the long-run equilibrium relationship: the case of city-gate and residential natural gas prices

Arano, K. and Velikova, M. *Energy Economics*, 2010, 32, (4), 901–907.

This paper examines market cointegration of city-gate and residential natural gas prices. Cointegration of gas prices across different segments of the industry provides evidence that deregulation has resulted in a more integrated, competitive natural gas industry where gas prices converge into a long-run equilibrium. The results indicate prices further down the distribution line, the final two points of consumption, are cointegrated for a majority of the US states post open access and retail unbundling, although there is little evidence of perfect market integration. The two price series likewise converge to the long-run equilibrium faster post open access and retail unbundling. Results relative to state level unbundling (choice programs) reveal mixed outcomes with a few states without retail unbundling exhibiting market integration while some states with full unbundling exhibiting non-cointegration.

11/00530 Europe lags behind in shale gas race

Anon., *Oil and Energy Trends*, 2010, 35, (9), 7–8.

Shale gas is difficult and expensive to produce, particularly in Europe. However, as North Sea crude oil reserves diminish and over 60% of Europe's gas is imported, the estimated 500 trillion cubic feet of shale gas deposits are becoming a more attractive option. Poland is currently leading the way in investigating exploration potential, however, Germany, Sweden and the Baltic Republics are also showing interest. In England too there are investigations underway in Dorset in the south-west and Lancashire in the north.

11/00531 Hydrogen is not an Utopia for Turkey

Celiktas, M. S. and Kocar, G. *International Journal of Hydrogen Energy*, 2010, 35, (1), 9–18.

The aim of this study was to explore how the future of technological developments in hydrogen will be shaped in Turkey by using a two-round Delphi method undertaken to determine and measure the expectations of the sector representatives through online surveys where a total of 60 experts responded from 18 different locations. The article discusses not only the expert sights on hydrogen technologies but also all bibliometrical approaches. The results showed that the hydrogen economy will enhance innovations as well as economic prosperities with the support of appropriate policies. Formulating such policies requires a timely and detailed understanding of the latest R&D trends and developments in science and technology policy in all developed countries, and the comprehensive analysis of these developments to enable accurate predictions of future science and technology trends.

11/00532 LPG characterization and production quantification for oil and gas reservoirs

Liang, B. *et al. Journal of Natural Gas Science and Engineering*, 2010, 2, (5), 244–252.

Liquefied petroleum gas (LPG) refers to the gas extracted and liquefied from the separator gas in a processing plant and mainly consists of propane (C_3) and butane (C_4). Many offshore projects have restrictions on flaring gases and special fiscal terms make extracted liquids significantly more valuable than oil and condensate in some cases, which in turn impact the economics of many projects. This paper for the first time systematically investigates LPG characterization and production quantification coupled together with reservoir simulation. Detailed calculations of LPG yields from both gas cap and solution gas are given. LPG yield of fluid is a function of the initial gas–oil ratio (GOR), gas specific gravity, and separator condition: LPG yield, which is lower in the gas cap compared to the solution gas of the same reservoir, has a good correlation with gas specific gravity and is impacted by separator conditions. The concept of LPG-produced GOR correlation curve is introduced and applied together with gas production rate to predict LPG production. Correlation curves depend on reservoir fluid properties and development strategies. Generated from flashing the mixtures of different proportions of oil and gas samples, LPG-produced GOR correlation curve has a good agreement with the results from reservoir compositional simulation and can be coupled with various forecasting tools in reservoir engineering. Lean gas injection has an insignificant impact on LPG recovery but can substantially improve the recovery of total liquid (oil and condensate). The paper also shows that lumping C_3 and C_4 as one pseudocomponent is suitable.

11/00533 Performance improvement of a 70 kWe natural gas combined heat and power (CHP) system

Zhao, X. L. *et al. Energy*, 2010, 35, (4), 1848–1853.

Combined heat and power is the simultaneous production of electricity and heat. CHP plants produce energy in an efficient way. A natural gas CHP system based on an internal combustion engine (ICE) is described, which has been set up at the Building Energy Research Center in Beijing, China. The system is composed of an ICE, a flue gas heat exchanger, a jacket water heat exchanger and other assistant facilities. The ICE generates power on-site, and the exhaust of the ICE is recovered by the flue gas heat exchanger, and the heat of the engine jacket is recovered by the jacket water heat exchanger to district heating system. In order to improve the performance of the system, an absorption heat pump (AHP) is adopted. The exhaust of the ICE drives the AHP to recover the sensible and latent heat step by step, and the temperature of the exhaust could be lowered to below 30 °C. In this paper, the performance of the new system were tested and compared with conventional cogeneration systems. The results show that the new CHP system could increase the heat utilization efficiency 10% compared to conventional systems in winter. All the results could be valuable references for the improvement of the CHP system.

11/00534 Price dynamics of natural gas and the regional methanol markets

Masih, A. M. M. *et al. Energy Policy*, 2010, 38, (3), 1372–1378.

A 'methanol economy' based mainly on natural gas as a feedstock has a lot of potential to cope with the current and ongoing concerns for energy security along with the reduction of carbon dioxide emissions. It is, therefore, important to examine the price dynamics of methanol in order to ascertain whether the price of methanol is mainly natural-gas-cost driven or demand driven in the context of different regions. This paper is the first attempt to investigate the following questions. (i) Is the natural gas price significantly related to the regional methanol prices in the Far East, USA and Europe? (ii) Who drives the regional methanol prices? The paper is motivated by the recent and growing debate on the lead-lag relationship between natural gas and methanol prices. The findings, based on the most recently developed 'long-run structural modelling' and subject to the limitations of the study, tend to suggest: (i) natural gas price is cointegrated with the regional methanol prices, (ii) the within-sample error-correction model results tend to indicate that natural gas was driving the methanol prices in Europe and the United States but not in the Far East. These results are consistent, during most of the period under review (May 1998 to March 2007, with the surge in demand for methanol throughout the Far East, particularly in China, Taiwan and South Korea, which appears to have played a relatively more dominant role in the Far East compared to that in Europe and the USA within the framework of the dynamic interactions of input and product prices. However, during the post-sample forecast period as evidenced in the variance decompositions analysis, the emergence of natural gas as the main driver of methanol prices in all three continents is consistent with the recent surge in natural gas price fuelled mainly, among others, by the strong hedging activities in the natural gas futures/options as well as refining tightness (similar to those that were happening in the crude oil markets).

Derived gaseous fuels

11/00535 Autothermal reforming of methane over $Rh/Ce_{0.5}Zr_{0.5}O_2$ catalyst: effects of the crystal structure of the supports

Cao, L. *et al. Fuel Processing Technology*, 2010, 91, (3), 306–312.

Autothermal reforming of methane (ATR) was studied over Rh catalysts supported on $Ce_{0.5}Zr_{0.5}O_2$ solid solution, which were synthesized by four different routes, including reverse micro-emulsion (ME), co-precipitation (CP), urea-combustion (UC) and sol–gel (SG) method. The textural and structural properties of the as-prepared solid solutions were carefully examined by means of BET, TEM, XRD and Raman techniques. Results showed that the ME sample exhibited a single cubic phase, whereas tetragonal or mixed phases such as cubic CeO_2-rich and tetragonal ZrO_2-rich phases, were found in the case of CP, UC and SG. Vegard's rule revealed that the homogeneity of these as-prepared solid solutions followed the order of ME > CP > UC > SG. TPR and CO-pulse experiments were adopted to evaluate the reducibility and the oxygen storage capacity (OSC) of the catalysts. It was found that the more homogenous the solid solution is, the more reducibility it is, i.e. both the reducibility and OSC followed the same order as that of homogeneity. Rh/ME showed the highest activity and H_2/CO ratio and such performance was maintained without significant loss during 10 h experiment. On the contrary, the other three catalysts having mixed phases showed remarkably deactivation in terms of H_2/CO due to the loss of BET area. To elucidate the resistance toward carbon formation of these catalysts, methane decomposition experiments and following temperature-programmed-oxidation (TPO) were studied. As expected, the resistance toward carbon formation could be enhanced by the improved OSC of the catalyst.

11/00536 Combustion of syngas in a pressurized microturbine-like combustor: experimental results

Delattin, F. *et al. Applied Energy*, 2010, 87, (4), 1441–1452.

The different routes for power production from biomass often lead to an intermediary product such as a synthesis gas or syngas, which is typically rich in hydrogen and carbon monoxide. The simple design, fuel flexibility and size, which often matches the amount of waste energy available in industrial sites, makes microturbines an attractive solution for on-site, decentralized power generation using a limited range of alternative fuels such as synthetic gas. The properties of the synthetic fuel differ from properties of natural gas and a detailed experimental study with a separated microturbine-like pressurized combustor is therefore necessary. The present article reviews the experimental results obtained by gradually switching the fuel feed from natural gas to wet syngas in a pressurized, slightly modified lean premix microturbine combustor. Temperature profiles, pressure, emissions and flame imaging were closely monitored to detect possible problems in operability of the combustor caused by the strong difference in fuel characteristics. No problems regarding auto-ignition, dynamic or static instability were observed throughout the test-run. Temperature profiles stayed well within allowable limits and did not reveal any significant shift in flame anchoring position. The combustion of syngas during full or part load of the combustor produced remarkably low NO_x and CO emissions. The microturbine combustor achieved stable full load combustion of syngas at the end of the test-run.

11/00537 Dry catalytic partial oxidation of diesel–fuel distillates into syngas

Mundschau, M. V. *et al. Fuel*, 2010, 89, (6), 1202–1211.

Volatile compounds distilled below 205 °C from diesel fuel are reformed into synthesis gas by *dry* catalytic partial oxidation using porous membrane reactors, eliminating complex liquid–fuel injectors and fuel–air mixers, greatly simplifying reformers for applications with solid-oxide fuel cells and NO_x traps. For distillates utilizing 20 wt% of the diesel fuel, 88 mol% of the carbon is converted into CO and 75 mol% of the hydrogen into H_2. Rationale is as follows: long-chain *n*-alkanes such as *n*-hexadecane, with normal boiling point, 286.5 °C, but autoignition temperature, 205 °C, are the least thermally stable hydrocarbons in diesel fuel. If attempts are made to vaporize diesel fuel under oxygen-lean conditions without precautions, long-chain *n*-alkanes crack at autoignition temperatures forming radicals that initiate polymerization. By eliminating more troublesome compounds by distillation, and by effusing cooler air through porous ceramic membranes to react radicals with oxygen, carbon deposition is largely suppressed. A perovskite catalyst, fed pre-heated air at >900 °C, provides a reservoir of mobile lattice oxygen to react with adsorbed carbon. In continuous runs of 72 h, carbon deposition was negligible in the reactor, on the catalyst, and in the exhaust, except for minor graphite deposited onto walls near the catalytic hot zone.

11/00538 Experimental study on pressure drops in a dividing wall distillation column

Barroso-Muñoz, F. O. *et al. Chemical Engineering and Processing: Process Intensification*, 2010, 49, (2), 177–182.

Previous studies in the fields of process design and process control have shown the potential benefits that can be achieved through the implementation of thermally coupled distillation sequences, in particular, the dividing wall distillation column. The dividing wall distillation column meets important goals of process intensification, including energy savings, reduction in carbon dioxide emissions and miniaturization. In this paper, an experimental study on the hydrodynamic behaviour of a dividing wall distillation column is presented. Several different values for gas and liquid velocities were tested in order to measure pressure drops and identify operational regions; the air/water system was used as the basis for the experimental setup. Results regarding pressure drops provide operational limits for the operation of the packed dividing wall distillation column. According to the results, the experimental dividing wall column can be operated at turbulent regime that is associated to proper mass transfer.

11/00539 Kinetics investigation of direct natural gas conversion by oxidative coupling of methane

Farsi, A. *et al. Journal of Natural Gas Science and Engineering*, 2010, 2, (5), 270–274.

Since 1982 there has been much research on the oxidative coupling of methane (OCM) process. The main obstacle for converting methane directly to more valuable products by heterogeneous catalysis is the low selectivity at high conversions; the products are more reactive than methane. The main goal of this work is to study the kinetics of OCM

reactions and classify them. It is found that with considering almost all reaction steps of the other models, a previously published reaction network has the best accuracy in comparison with the other models.

11/00540 Performance analysis of a heavy duty combined cycle power plant burning various syngas fuels

Sánchez, D. *et al. International Journal of Hydrogen Energy*, 2010, 35, (1), 337–345.

This paper presents a performance analysis of state of the art combined cycles power plants burning a number of syngas fuels. The first part of the analysis focuses on the effect of gas composition on the rated performance of the plant drawing two main conclusions. First, higher pressure ratio and lower firing temperature are found at turbine inlet. Second, the pressure at which fuel is supplied to the gas turbine plays an essential role in the power capacity of the engine. With respect to the steam cycle, no major effects are appreciated except for very low LHV fuels. In the second part of the work, the annual performance of the engine subjected to a typical load profile and real ambient and market conditions is studied. Differences in total incomes are appreciated depending on fuel composition and the concern about carbon emissions is highlighted.

11/00541 Performance analysis of a syngas-fed gas turbine considering the operating limitations of its components

Kim, Y. S. *et al. Applied Energy*, 2010, 87, (5), 1602–1611.

As the need for clean coal technology grows, research and development efforts for integrated gasification combined cycle (IGCC) plants have increased worldwide. An IGCC plant couples a gas turbine with a gasification block. Various technical issues exist in designing the entire system. Among these issues, the matching between the gas turbine and the air separation unit is especially important. In particular, the operating condition of a gas turbine in an IGCC plant may be very different from that of its original design. This study analyses the impact of the use of syngas on operating conditions of the gas turbine in an IGCC plant. The authors evaluated the performance of a gas turbine under operating limitations in terms of compressor surge and turbine metal temperature. Although a lower degree of integration may theoretically allow higher gas turbine power output and efficiency, it causes a reduction in compressor surge margin and overheating of the turbine metal. The turbine overheating problem may be solved using several methods, such as a reduction in the firing temperature or an increase in the turbine cooling air. The latter yields a much smaller performance penalty. To achieve an acceptable margin for the compressor surge, either further reduction in the firing temperature or further increase in the coolant is required. Ventilation of some of the nitrogen generated by the air separation unit, i.e. a reduction of the nitrogen supply to the combustor, is another option. Coolant modulation yields the lowest performance penalty. Reduction of the nitrogen supply provides much greater system power output than control of the firing temperature. For nitrogen flow and firing temperature controls, there are optimal levels of integration degrees in terms of net system power output and efficiency.

11/00542 Recovery of useful lighter fuels from petroleum residual oil by oxidative cracking with steam using iron oxide catalyst

Funai, S. *et al. Chemical Engineering Science*, 2010, 65, (1), 60–65.

In the petroleum industry it is desirable to produce lighter hydrocarbons such as gasoline, kerosene and gas–oil from unused heavy oils. Thus, a zirconia-supporting iron oxide catalyst (ZrO_2–FeO_X catalyst) to decompose petroleum residual oil (atmospheric distilled residual oil) with steam has been developed. In addition, it was found that the incorporation of Al_2O_3 among FeO_X crystals is effective in improving the catalytic activity and stability of the ZrO_2–FeO_X catalyst. In this study, the effects of Al_2O_3 and ZrO_2 content in FeO_X–based catalysts on catalytic activity and stability were investigated. Furthermore, the FeO_X–based catalyst was applied to the decomposition of extra heavy oils such as vacuum-distilled residual oil and Orimulsion. These extra heavy oils were effectively decomposed over the ZrO_2–Al_2O_3–FeO_X catalyst with steam, and the yields of lighter hydrocarbon reached to above 60%.

11/00543 Synthesis and oxygen transport properties of $La_{0.2}Sr_{0.8}Fe_{1-x}TixO_{3-\delta}$ ($x = 0.2$, 0.4) intended for syn-gas production

Bartonickova, E. *et al. Journal of the European Ceramic Society*, 2010, 30, (2), 605–611.

Perovskites in the system $La_{0.2}Sr_{0.8}Fe_{1-x}TixO_{3-\delta}$ exhibit high stability at severe reducing conditions and high temperatures. This paper reports on the processing and oxygen transport properties of two compositions: $La_{0.2}Sr_{0.8}Fe_{1-x}TixO_{3-\delta}$ ($x = 0.2$, 0.4). Single-phase powders were synthesized by spray pyrolysis (SP) and solid state reaction (SSR). The resulting average particle sizes (BET) ranged from 140 nm (SP) to 1090 nm (SSR). Samples were prepared by CIP and pressureless sintered between 1200 and 1250 °C for 8–12 h. Sintered densities ranged from 97 (SSR) to 99% (SP) and grain size was less than 1.5 μm. The average TEC varied in the range $(13.8–14.6) \times 10^{-6}\,K^{-1}$ at 300–600 °C and $(21.3–28.9) \times 10^{-6}\,K^{-1}$ at 600–800 °C. Surface exchange coefficients and bulk diffusion coefficients in terms of temperature and p_{O_2} were assessed by the method of electrical conductivity relaxation. A simple defect model was applied to explain electrical conductivity and bulk diffusion behaviour.

11/00544 Temperature programmed desorption of coal gases – chemical and carbon isotope composition

Buzek, F. and Lnenickova, Z. *Fuel*, 2010, 89, (7), 1514–1524.

Fresh and stored coals from the United States (New Mexico, Colorado and Wyoming) and Czech Republic (North Bohemian and Upper Silesian Basins) were studied by the method of temperature programmed desorption. Desorbed gases were analysed for their chemical and carbon isotope composition. Upon heating from room temperature with a constant rate of 40 °C/min, two desorption phases were observed: low temperature desorption of CH_4 and CO_2 with a maximum intensity between 50 and 80 °C and high temperature desorption of CO_2 only between 150 and 210 °C. The desorption of (residual) primary coalbed gas was compared with the desorption of re-adsorbed gases. The $\delta^{13}C$ values of the desorbed gases changed due to isotopic fractionation during coal degassing. Kinetic isotope effects were evaluated by comparing the gas desorption from fresh and stored coals from the same seams. Mean values of isotope enrichment during desorption are 2‰ and 1.9‰ for CO_2 and CH_4, respectively.

11/00545 The production of synthetic natural gas (SNG): a comparison of three wood gasification systems for energy balance and overall efficiency

van der Meijden, C. M. *et al. Biomass and Bioenergy*, 2010, 34, (3), 302–311.

The production of synthetic natural gas from biomass (Bio-SNG) by gasification and upgrading of the gas is an attractive option to reduce CO_2 emissions and replace declining fossil natural gas reserves. Production of energy from biomass is approximately CO_2 neutral. Production of Bio-SNG can even be CO_2 negative, since in the final upgrading step, part of the biomass carbon is removed as CO_2, which can be stored. The use of biomass for CO_2 reduction will increase the biomass demand and therefore will increase the price of biomass. Consequently, a high overall efficiency is a prerequisite for any biomass conversion process. Various biomass gasification technologies are suitable to produce SNG. The present article contains an analysis of the Bio-SNG process efficiency that can be obtained using three different gasification technologies and associated gas cleaning and methanation equipment. These technologies are: (1) entrained flow, (2) circulating fluidized bed and (3) allothermal or indirect gasification. The aim of this work is to identify the gasification route with the highest process efficiency from biomass to SNG and to quantify the differences in overall efficiency. Aspen Plus® was used as modelling tool. The heat and mass balances are based on experimental data from literature and the authors' own experience. Overall efficiency to SNG is highest for allothermal gasification. The net overall efficiencies on LHV basis, including electricity consumption and pre-treatment but excluding transport of biomass are 54% for entrained flow, 58% for CFB and 67% for allothermal gasification. Because of the significantly higher efficiency to SNG for the route via allothermal gasification, ECN is working on the further development of allothermal gasification. ECN has built and tested a 30 kW_{th} lab scale gasifier connected to a gas cleaning test rig and methanation unit and presently is building a 0.8 MWth pilot plant, called Milena, which will be connected to the existing pilot scale gas cleaning.

LNG

11/00546 Calculation models for prediction of liquefied natural gas (LNG) ageing during ship transportation

Miana, M. *et al. Applied Energy*, 2010, 87, (5), 1687–1700.

A group of European gas transportation companies within the European Gas Research Group launched in 2007 the 'MOLAS' Project to provide a software program for the analysis of the liquefied natural gas (LNG) ageing process during ship transportation. This program contains two different modelling approaches: a physical algorithm and an 'intelligent' model. Both models are fed with the same input data, which is composed of the ship characteristics (BOR and capacity), voyage duration, LNG composition, temperature, pressure, and volume occupied by liquid phase at the port of origin, together with pressure at the port of destination. The results obtained are the LNG composition, temperature and liquid volume at the port of destination. Furthermore, the physical model obtains the evolution over time of such variables en route as it is based on unsteady mass balances over the system, while

the i-model applies neural networks to obtain regression coefficients from historical data composed only of origin and destination measurements. This paper describes both models and validates them from previous published models and experimental data measured in ENAGAS LNG regasification plants.

11/00547 Cooperation among liquefied natural gas suppliers: is rationalization the sole objective?

Massol, O. and Tchung-Ming, S. *Energy Economics*, 2010, 32, (4), 933–947.

This paper examines the development of cooperative strategies between countries exporting liquefied natural gas (LNG) and members of the Gas Exporting Countries Forum (GECF). This economic study focuses specifically on an often-raised scenario: the emergence of a cooperative approach designed with the sole aim of logistic rationalization, and which would not have any effect on LNG prices. First the annual gains that may result from this market-power-free cooperative approach were assessed using a simple static transportation model. The numerical results obtained suggest that, in the absence of a gain redistribution policy, this cooperative strategy will probably not be adopted because cooperation would not be a rational move for some exporters. The problem of gain sharing is then formulated using cooperative game theory concepts. Several gain-sharing methods have been studied, including the Shapley value and various nucleolus-inspired concepts. The results suggest that the choice of a redistribution policy appears relatively restricted. Out of the methods studied, only one – per capita nucleolus – satisfies two key requirements: core belonging and monotonicity (in the aggregate). Lastly, consideration is given to how cooperation may give rise to a coordination cost and try to determine the maximum amount of this cost. In view of the low level of this amount and the relative complexity of the sharing method implemented, it is concluded that the credibility of a logistic cooperation scenario exempt from market power should be reappraised.

11/00548 Energy and exergy analyses of urban waste incineration cycle coupled with a cycle of changing LNG to pipeline gas

Meratizaman, M. *et al. Journal of Natural Gas Science and Engineering*, 2010, 2, (5), 217–221.

Garbage incineration systems are originally designed solely for the purpose of disposing urban waste. Today however, besides environmental issues, taking advantages of the heating value of fuels is also a subject of attention. Nowadays the schemes which are characterized by best use of energy resources are the only ones which are economically justified. Thus, cogeneration systems have been developed for the better usage of energy resources. In the present case study, a waste incineration system is coupled with a power cycle. The power cycle uses hot gases produced from combustion of waste material. Cooling energy of liquefied natural gas (LNG) is used to cool the operating fluid in the power cycle. In this paper, the increased power of the cycle resulting from the addition of pipeline gas to the waste incineration system is studied. At the same time, the amount of pipeline gas produced from LNG is studied as well. A detail exergy and energy analyses is used in this study.

11/00549 Use of sophisticated heat exchanger simulation models for investigation of possible design and operational pitfalls in LNG processes

Skaugen, G. *et al. Journal of Natural Gas Science and Engineering*, 2010, 2, (5), 235–243.

The simulation rating programs S-FIN for PFHE and S-PLATE for PHE have been developed at SINTEF Energy Research. These tools can be incorporated in process simulation environments like PRO/II and Aspen HYSYS®, and thus be used as an integrated part when doing process energy simulation and optimization. Static flow instabilities that can occur in heat exchangers used in cryogenic services are discussed. Examples on how to perform, and how to interpret, a Ledinegg instability analysis, are shown using the developed programs. With the well-known single mixed refrigerant process as a case study, a thermally valid plate-fin heat exchanger was designed that was subjected to Ledinegg instability. Remedies to avoid this and the effect on the process energy consumption are discussed. For the selected case, the compressor power increased by 14% going from an unstable to a stable design/operation. The examples show that detailed heat exchanger simulations should be performed as a part of process optimization.

Hydrogen generation and storage

11/00550 A novel Ni–Mg–Al–CaO catalyst with the dual functions of catalysis and CO_2 sorption for H_2 production from the pyrolysis–gasification of polypropylene

Wu, C. and Williams, P. T. *Fuel*, 2010, 89, (7), 1435–1441.

A novel Ni–Mg–Al–CaO catalyst/sorbent has been prepared by integration of the catalytic and CO_2 absorbing properties of the material to maximize the production of hydrogen. The prepared catalyst was tested for hydrogen production from the pyrolysis–gasification of polypropylene by using a two-stage fixed-bed reaction system. X-ray diffraction (XRD), thermogravimetric analysis (TGA) and scanning electron microscopy (SEM)-energy dispersive X-ray spectrometry (EDXS) were used to characterize the prepared Ni–Mg–Al–CaO catalyst/sorbent. Ni–Mg–Al–CaO and calcined dolomite showed a stable carbonation conversion after several cycles of carbonation/calcination, while CaO showed a certain degree of decay. The calcined dolomite showed low efficiency for hydrogen production from pyrolysis–gasification of polypropylene. Increasing the gasification temperature resulted in a decrease of H_2/CO ratio for the Ni–Mg–Al catalyst mixed with sand; however, a stable H_2/CO ratio (around 3.0) was obtained for the Ni–Mg–Al–CaO catalyst. An increased Ni–Mg–Al–CaO catalyst/polypropylene ratio promoted the production of hydrogen from the pyrolysis–gasification of polypropylene. Approximately 70 wt% of the potential H_2 production was obtained, when the Ni–Mg–Al–CaO catalyst/polypropylene ratio and gasification temperature were 5 and 800 °C, respectively.

11/00551 Combined pre-reforming–desulfurization of high-sulfur fuels for distributed hydrogen applications

Muradov, N. *et al. Fuel*, 2010, 89, (6), 1221–1229.

A major challenge facing the future hydrogen economy is the issue of hydrogen fuel delivery and distribution. In the near term, it may be necessary to deliver high-density hydrocarbon fuels (e.g. diesel fuel) directly to the end-user (e.g. a fuelling station) wherein it is reformed to hydrogen, on demand. This approach has the advantages of utilizing the existing fuel delivery infrastructure, and the fact that more energy can be delivered per trip when the tanker is filled with diesel instead of liquefied or compressed hydrogen gas. Reforming high-sulfur hydrocarbon fuels (e.g. diesel, JP-8, etc.) is particularly challenging due to rapid deactivation of conventional reforming catalysts by sulfurous compounds. A new on-demand hydrogen production technology for distributed hydrogen production is reported. In this process, first, the diesel fuel is catalytically pre-reformed to shorter chain hydrocarbons (C_1–C_6) before being fed to the steam reformer, where it is converted to syngas and further to high-purity hydrogen gas. In the pre-reformer, most sulfurous species present in the fuel are converted to H_2S. Desulfurization of the pre-reformate gas is carried out in a special regenerative redox system, which includes an iron-based scrubber coupled with an electrolyser. The integrated pre-reformer and sulfur-scrubbing unit operated successfully for 100 h at desulfurization efficiency of greater than 95%.

11/00552 Development and characteristics of rapidly formed hydrogen-producing granules in an acidic anaerobic sequencing batch reactor (AnSBR)

Liang, D.-W. *et al. Biochemical Engineering Journal*, 2010, 49, (1), 119–125.

This study investigated the development and characteristics of rapidly formed hydrogen-producing granules (HPGs) in an acidic anaerobic sequencing batch reactor (AnSBR). When subjecting the AnSBR suspended sludge to heat-shock (80 °C for 20 min) and acidic pretreatment (pH 2.0 for 24 h) subsequently, granules were formed within the first 10 days of the AnSBR operation at pH 5.5. After subsequent second time heat-shock of the granules on day 35, hydrogen yield increased significantly to 1.36 mol-H_2/mol-glucose with a headspace content of $65 \pm 7\%$ and was stable during the next 60 days running of the AnSBR. A typical mature HPG showed 1.7 ± 0.2 mm in diameter and had an average settling velocity of 43 m/h. The granules were comprised of uniform rod-shaped bacteria with a non-layered structure and multiple cracks on the surface. Three pure cultures, *Clostridium* sp. HP2, HP4 and HP7, were obtained from the enriched HPGs. Among the three isolates, strain HP4 showed the highest hydrogen yield of 1.41 (mol-H_2/mol-glucose) at a rate of 0.85 L-H_2/L/day (34.5 mmol-H_2/L/day). This study suggests that acid pretreatment, combining with the short settling time (30 min) and large exchange ratio (60%) of effluent, is applicable for rapid formation of HPGs in the AnSBR, which provides a promising approach for biological hydrogen production from the organic wastewater.

11/00553 Generation of H_2 gas from polystyrene and poly(vinyl alcohol) by milling and heating with $Ni(OH)_2$ and $Ca(OH)_2$
Tongamp, W. *et al. Fuel Processing Technology*, 2010, 91, (3), 272–276.
A two-step process to generate H_2 gas; first by milling polystyrene (PS) or poly(vinyl alcohol) (PVA) with $Ni(OH)_2$ and $Ca(OH)_2$, followed by heating of the milled product in the second-step was performed in this work. Polymer and hydroxide mixtures obtained after milling for 60 min and heating to 700 °C showed H_2, CH_4, H_2O, CO, and CO_2 as the main gaseous products with H_2 as the dominant gas generated between 350 and 500 °C. Analysis of the gaseous products by TG–MS and gas-chromatography, and solid products by TG–DTA and XRD shows that CO_2 gas was fixed as $CaCO_3$ at temperatures between 350 to 600 °C allowing generation of H_2 gas with concentrations over 95% for PS and over 98% for PVA. The results in this study show that milling of solid based hydrocarbon compounds with nickel and calcium hydroxides allows dispersion of nickel to hydrocarbon surfaces and facilitates C–C bond rupture in polymer(s) during heating at temperatures below 500 °C, at the same time calcium adsorbs CO_2. This process could be developed to treat hydrocarbon based wastes such as plastics, biomass or combinations at low temperatures avoiding syngas purification and separation steps.

11/00554 Hydrogen generation from liquid reforming of glycerin over Ni–Co bimetallic catalyst
Luo, N. *et al. Biomass and Bioenergy*, 2010, 34, (4), 489–495.
Glycerin is a low-cost renewable byproduct of the biodiesel industry, and can be reformed into hydrogen. Here the authors describe the development of cerium promoted nickel cobalt catalysts on alumina supports for the liquid phase reforming of aqueous glycerine in subcritical water. The bimetallic Ni–Co catalyst was prepared using the urea matrix combustion method over a wide range of compositions both with and without cerium. TPR profiles indicated a synergism between the metals, however, the catalysts deactivated due to carbon deposition as plaques, and in some compositions due to sintering. Cerium ($2Ce–Ni_1Co_3$) suppressed sintering and lowered methane selectivity by comparison with Ni_1Co_3 alone.

11/00555 Hydrogen production from solid reactions between $MAlH_4$ and NH_4Cl
Zhang, H. *et al. International Journal of Hydrogen Energy*, 2010, 35, (1), 176–180.
Solid reactions between alkali aluminum hydrides ($MAlH_4$, M = Li or Na) and NH_4Cl (at mole ratio 1:1) at 170 °C were investigated quantitatively using temperature programmed reaction (TPR), thermogravimetric analysis (TGA), differential scanning calorimetry (DSC) and X-ray diffraction (XRD). The release of 3 mol of H_2 from per mole of $MAlH_4$ was measured, corresponding to 5.6 wt% H_2 capacity for the $NaAlH_4/NH_4Cl$ system and 6.6 wt% for $LiAlH_4/NH_4Cl$, respectively. By ball milling of the precursor compounds prior to the mixing, the reaction proceeded fast and NH_3 production as the by-product could be avoided. The quick solid reactions may be attributed to the low melting temperatures of $MAlH_4$ and the exothermic nature of the reactions. The reaction mechanism was also discussed.

11/00556 Improving hydrogen storage properties of covalent organic frameworks by substitutional doping
Li, F. *et al. International Journal of Hydrogen Energy*, 2010, 35, (1), 266–271.
The authors proposed a possible way of promoting the binding of H_2 molecules on covalent organic frameworks crystals via substituting the bridge C_2O_2B rings with different metal-participated rings, which can naturally avoid the clustering of metal atoms. First-principles calculations on both crystalline phase and molecular fragments show that the H_2 binding energy can be enhanced by a factor of four with regard to the undoped crystal, i.e. reaching about 10 kJ/mol. Grand canonical Monte Carlo simulations further confirm that such substitutional doping would improve the room temperature hydrogen storage capacity by a factor of two to three.

11/00557 Ni(II)–Mg(II)–Al(III) catalysts for hydrogen production from ethanol steam reforming: influence of the activation treatments
Romero, A. *et al. Catalysis Today*, 2010, 149, (3–4), 407–412.
The effect of the Ni(II)–Mg(II)–Al(III) layered double hydroxide (LDH) activation conditions over the surface and bulk composition and the catalytic performance in ethanol steam reforming (ESR) was studied. Ternary oxides were prepared by thermal decomposition of LDHs synthesized using the homogeneous precipitation method with urea. A catalyst precursor was submitted to two different activation treatments: calcinations at 400, 500, 600 and 700 °C with subsequent reduction at 720 °C, or direct reduction at 720 °C. The samples were characterized by sorptometry, H_2 chemisorption, ICP chemical analysis, thermogravimetric analysis, X-ray diffraction, X-ray photoelectronic spectroscopy and temperature programming reduction. The catalysts obtained by calcination at 600 °C and then reduction at 720 °C and those directly reduced at 720 °C showed the better performance in ESR. The precursor submitted to a proper thermal treatment develops, through a decoration-demixing process, a Ni(II)-poor spinel-type shell onto NiO domains.

11/00558 Reversible hydrogen storage in electrospun polyaniline fibers
Srinivasan, S. S. *et al. International Journal of Hydrogen Energy*, 2010, 35, (1), 225–230.
Due to its many physisorption sites as well as chemisorption sites, polyaniline (PANI) has been investigated for hydrogen storage purposes. The PANI was produced in house via traditional chemical synthesis methods and then electrospun to produce fibres. These PANI fibres were investigated and compared with standard bulk PANI and found to be stable up to 150 °C. When investigating PANI fibres, using PCT measurements, it was found that a reversible hydrogen storage capacity of ~3–10 wt% could be obtained at different temperatures. Hydrogen kinetic sorption measurements in prolonged cycles (up to 66 cycles) reveal an uptake and release of >6–10 wt% on these PANI materials. The importance of the type of measurement is discussed as to its effect on the morphology and structure of the PANI nanofibres. The surface morphologies before and after hydrogen sorption on these PANI fibres encompass significant changes in the microstructure (nanofibrallar swelling effect). Detailed chemical and physical characterization of the PANI fibres is reported as part of this work.

04 BY-PRODUCTS RELATED TO FUELS

11/00559 Activated carbon injection for mercury control: overview
Sjostrom, S. *et al. Fuel*, 2010, 89, (6), 1320–1322.
Full-scale evaluations of the commercial feasibility of activated carbon injection (ACI) for mercury control in coal-fired power plants have been underway in North America since 2001 through DOE, EPRI and industry-funded projects. Commercial injection systems began to be sold to the power generation industry in 2005 and ACI is now considered the most robust technology for mercury control at many coal-fired units. Successful widespread implementation of this technology throughout this industry will require continued development efforts including: (1) understanding the impacts of technologies to control other pollutants, such as SO_3, for the enhancement of particulate control or selective catalytic reduction (SCR) for NO_x control, (2) options to continue using ash containing activated carbon in concrete, (3) techniques to assure the quality of delivered carbon, (4) techniques to improve the effectiveness of activated carbon, and (5) facilities to produce additional carbon supply. An overview of activated carbon injection for mercury control will be presented including the range of expected control levels, costs, balance-of-plant issues, recent developments to reduce overall control costs for many common air pollution control configurations, and developments to overcome complications caused by some new control configurations. An update on carbon supply and progress on ADA's activated carbon manufacturing facility will also be provided.

11/00560 Behavior features of soot combustion in diesel particulate filter
Martirosyan, K. S. *et al. Chemical Engineering Science*, 2010, 65, (1), 42–46.
Infra-red measurements of the combustion of particulate matter deposited on the surface of a single-layer diesel particulate filter showed that it may proceed in three different modes: either by a moving hot zone emanating from a single ignition point, or hot zones generated at several different ignition points or uniform combustion all over the surface. The velocity of the downwards moving temperature front exceeds that of the upstream front bounding the hot zone. The number of ignition points increases as the particulate matter loading is decreased. The highest temperature rise is obtained by a downward moving hot zone. Avoiding this mode of combustion decreases the probability of excessive hot zone formation during the particulate matter regeneration.

11/00561 Control of ash related problems in a large scale tangentially fired boiler using CFD modelling
Vuthaluru, H. R. and Vuthaluru, R. *Applied Energy*, 2010, 87, (4), 1418–1426.

This study developed a three-dimensional combustor model for predicting the performance of a full-scale tangential fired (TF) boiler. It also aimed to determine the flow patterns of the gas and coal particles, with an emphasis on formation mechanism of gas flow deviations and uneven temperature on the super-heaters, re-heaters and divisional super-heater sections of the furnace. The importance of these simulations is to identify the locations of optimum additive injection ports to achieve maximum impact of additives in the combustion process to minimize the temperature deviation and reduce ash-related issues. This provides a classic example of numerical investigation into the problem of turbulent reacting flows in large-scale furnaces employed in thermal power plants for the remediation of ash deposition problems. This work also provides an investigation of the influence of number of tripped burners on the characteristics of the flow and thermal fields. Excellent agreement between the simulation results and key boiler design values and available site operation records following full-scale trials indicate that the calculations are reliable. The results obtained are directly relevant to coal-fired utilities for not only demonstrating the effectiveness of computational fluid dynamics (CFD) based tools in combating operational issues but also provides an alternative to conventional remediation strategies.

11/00562 Flow properties and rheology of slag from coal gasification

Song, W. *et al. Fuel*, 2010, 89, (7), 1709–1715.

The authors have studied the rheological characteristics of Texaco gasifier slag at high-temperature. Slag samples have been analysed by X-ray fluorescence, X-ray diffraction, and scanning electron microscopy. The rheological behaviour of the slag has been investigated experimentally using a high-temperature rheometer at temperatures between 1200 °C and 1340 °C. The effects of the shear rate and temperature on the rheological behaviour of the slag have been explored. Moreover, the observed rheological behaviour of the slag has been correlated with its solid-phase content, as calculated with the aid of the computer software package FactSage. The results show that the sensitivity of the slag viscosity to temperature decreases with increasing rotation speed. Above its liquidus temperature calculated by FactSage, the slag behaves as a Newtonian fluid; below its liquidus temperature, however, the rheological behaviour of the slag becomes non-Newtonian owing to its increased solid-phase content. Meanwhile, slag containing a number of crystalline particles shows dramatic shear-thinning and thixotropic behaviour. Moreover, the shear-thinning behaviour of the slag becomes ever more distinct as the temperature is decreased. The yield stress values of the slag and the number and particle size of the crystalline particles in the slag increase with decreasing temperature.

11/00563 Gasoline-range hydrocarbon synthesis over Co/SiO_2/HZSM-5 catalyst with CO_2-containing syngas

Li, Yu-P. *et al. Fuel Processing Technology*, 2010, 91, (4), 388–393.

Selective synthesis of gasoline-range hydrocarbons (C_5–C_{12}) was investigated in a fixed-bed micro reactor using two series of CO_2-containing syngas with various mole $CO_2/(CO + CO_2)$ and $H_2/(CO + CO_2)$ ratios, where Fischer–Tropsch synthesis (FTS) and *in situ* hydrocracking/hydroisomerization were performed over bifunctional Co/SiO_2/HZSM-5 catalyst. CO_2 was converted at 0.15–0.55 of $CO_2/(CO + CO_2)$ ratio under H_2-rich condition ($H_2/(CO + CO_2) = 2.0$), highest conversion of 20.3% at 0.42. Further increasing CO_2 content decreased CO_2 conversion and quite amount of CO_2 acted as diluting component. For the syngas with low H_2 content or $H_2/(CO + CO_2)$ ratio(< 1.85, $H_2/CO = 2.0$), the competitive adsorption of CO, H_2 and CO_2 resulted in low CO, CO_2 and total carbon conversion, which was 57.9%, 12.7% and 31.4% respectively at 0.74 of $H_2/(CO + CO_2)$ ratio($H_2/CO/CO_2/N_2 = 40.8/20.4/34.8/4$). FTS results indicated that high H_2 content and proper $H_2/(CO + CO_2)$ ratio were favourable for the conversion of CO_2-containing syngas. More than 45% selectivity to gasoline-range hydrocarbons including isoparaffins was obtained under the two series of syngas. It was also tested that the catalytic activity of Co/SiO_2/HZSM-5 kept stable under CO_2-containing syngas($< 7.5\%$). And the quick catalytic deactivation under high CO_2 containing syngas($H_2/CO/CO_2/N_2 = 45.3/23.2/27.1/3.06$) was due to carbon deposition and pore blockage by heavy hydrocarbon, tested by thermal gravimetry, N_2 physisorption and scanning electron microscopy.

11/00564 Heavy metals distribution characteristics in different particle size of bottom ash after agglomeration/defluidization at various fluidization parameters

Lin, C.-L. and Yeh, T. Y. *Biomass and Bioenergy*, 2010, 34, (4), 428–437.

This study examined the effects of variations in alkali and alkaline earth metal content, bed material diameter, static bed height and gas velocity in a fluidized-bed combustion process to understand the distribution of heavy metals in bottom ash after agglomeration/defluidization. A smaller diameter bed material increased the relative abundance of small particle sizes in the bottom ash due to attrition and thermal impact at high temperature. The addition of Na led to an increase in the large particle abundance of the bottom ash, likely due to the formation of a eutectic with a low melting point, causing agglomeration. The addition of Ca inhibited the agglomeration/defluidization and increased the abundance of large particles in the bottom ash. In general, heavy metal concentrations increased when the bottom ash size was smaller than 0.59 mm and larger than 0.84 mm. Regarding the different fluidization parameters, the bottom ash had the lowest concentration of heavy metals at 1.5 U_{mf}, an H/D of 2.1 and a bed material (silica) particle size of 0.645 mm. The concentrations of heavy metals in the bottom ash after Ca addition were higher than of those without Na or with Na only. Addition of Ca prolonged the operation time of fluidization and increased the feed quantity of heavy metal, helping the bed material adsorb more heavy metal. Therefore, the addition of Ca not only prolonged the fluidization time, reducing agglomeration/defluidization, but also resulted in a higher adsorption of heavy metals by the bed material, reducing their emission.

11/00565 Preparation and characterization of activated carbon from rubber-seed shell by physical activation with steam

Sun, K. and Jiang, J. C. *Biomass and Bioenergy*, 2010, 34, (4), 539–544.

The use of rubber-seed shell as a raw material for the production of activated carbon with physical activation was investigated. The produced activated carbons were characterized by nitrogen adsorption isotherms, scanning electron microscope, thermo-gravimetric and differential scanning calorimetric in order to understand the rubber-seed shell activated carbon. The results showed that rubber-seed shell is a good precursor for activated carbon. The optimal activation condition is: temperature 880 °C, steam flow 6 kg h^{-1}, residence time 60 min. Characteristics of activated carbon with a high yield (30.5%) are: specific surface area (S_{BET}) 948 $m^2 g^{-1}$, total volume 0.988 $m^3 kg^{-1}$, iodine number of adsorbent (q_{iodine}) 1.326 g g^{-1}, amount of methylene blue adsorption of adsorbent (q_{mb}) 265 mg g^{-1}, hardness 94.7%. It is demonstrated that rubber-seed shell is an attractive source of raw material for producing high capacity activated carbon by physical activation with steam.

11/00566 Role of microporosity and surface chemistry in adsorption of 4,6-dimethyldibenzothiophene on polymer-derived activated carbons

Seredych, M. *et al. Fuel*, 2010, 89, (7), 1499–1507.

Two carbon samples derived from poly(4-styrenesulfonic acid-co-maleic acid) based polymer by carbonization between 700 and 800 °C were oxidized to two different levels of surface acidity. The surfaces of resulting adsorbents were characterized by potentiometric titration, adsorption of nitrogen, FTIR, SEM/EDAX and thermal analysis. The materials were used as adsorbents of 4,6-dimethyldibenzothiophene (4,6-DMDBT) from hexadecane with initial concentration of sulfur between 10–150 ppm*w*. Although it was found that pores with diameter less than 10 Å govern the amount of 4,6-DMDBT adsorbed, that amount is enhanced when acidic groups are present in the larger pores owing to the contributions of specific interactions. Surface chemistry plays an important role in reactive adsorption and deposition of the products of surface reactions in the pore system.

11/00567 Thermal behavior of coal-tar pitch modified with BMI resin

Lin, Q. *et al. Journal of Analytical Applied Pyrolysis*, 2010, 87, (1), 29–33.

Coal-tar pitch was modified with a bismaleimide (BMI) resin. Rheological properties and carbonization behaviour of the pitch–BMI resin composites and optical texture of resultant semi-cokes were studied in this paper. The carbonization behaviour was studied by thermogravimetric analysis and Fourier transform infrared (FTIR) spectroscopy techniques. In addition, the optical texture of resultant semi-cokes was characterized by polarized-light microscopy. Results show that the BMI resin content has great effect on the viscosity of the pitch–BMI resin composites. When the BMI resin content is 40 wt%, the rheological behaviour of the pitch–BMI resin composite is similar to that of a thermosetting resin with a U-type curve. Moreover, the pitch–BMI resin composites have better thermal stability than coal-tar pitch. The addition of BMI resin results in an increase in carbonization yield by 6.5% when the BMI resin content is 40 wt% of the pitch–BMI resin composite. Also, the BMI resin has great effect on formation of the optical textures. When the BMI resin content is 10 wt% of the pitch–BMI resin composite, the addition of BMI resin clearly improves the development of anisotropy on carbonization and the optical texture is flow domain anisotropy. Furthermore, there are higher aromaticity and more condensed polynuclear structures in resultant semi-cokes with increasing heat treatment temperature.

11/00568 Transformation of CH_4 and liquid fuels into syngas on monolithic catalysts

Sadykov, V. *et al. Fuel*, 2010, 89, (6), 1230–1240.

Active components comprised of fluorite-like $Ln_x(Ce_{0.5}Zr_{0.5})_{1-x}O_{2-y}$ (Ln = La, Pr, Sm) and perovskite-like $La_{0.8}Pr_{0.2}Mn_{0.2}Cr_{0.8}O_3$ mixed oxides and their composites with yttria-doped zirconia (YSZ) promoted by precious metals (Pt, Ru) and/or Ni were supported on several types of heat-conducting substrates (compressed Ni–Al foam, Fecralloy foil or gauze protected by corundum layer, Cr–Al–O microchannel cermets, titanium platelets protected by oxidic layer) as well as on honeycomb corundum monolithic substrate. These structured catalysts were tested in pilot-scale reactors in the reactions of steam reforming of methane, selective oxidation of decane and gasoline and steam/autothermal reforming of biofuels (ethanol, acetone, anisole, sunflower oil). Applied procedures of supporting nanocomposite active components on monolithic/structured substrates did not deteriorate their coking stability in real feeds with a small excess of oxidants, which was reflected in good middle-term (up to 200 h) performance stability promising for further up-scaling and long-term tests. Equilibrium yield of syngas at short contact times was achieved by partial oxidation of decane and gasoline without addition of steam usually required to prevent coking. For the first time possibility of successive transformation of biofuels (ethanol, acetone, anisole, sunflower oil) into syngas at short contact times on monolithic catalysts was demonstrated. This was provided by a proper combination of active component, thermal conducting monolithic substrates and unique evaporation/mixing unit used in this research.

05 NUCLEAR FUELS

Scientific, technical

11/00569 A new code for predicting the thermo-mechanical and irradiation behavior of metallic fuels in sodium fast reactors

Karahan, A. and Buongiorno, J. *Journal of Nuclear Materials*, 2010, 396, (2–3), 283–293.

An engineering code to predict the irradiation behaviour of U–Zr and U–Pu–Zr metallic alloy fuel pins and UO_2–PuO_2 mixed oxide fuel pins in sodium-cooled fast reactors was developed. The code was named Fuel Engineering and Structural analysis Tool (FEAST). FEAST has several modules working in coupled form with an explicit numerical algorithm. These modules describe fission gas release and fuel swelling, fuel chemistry and restructuring, temperature distribution, fuel–clad chemical interaction, and fuel and clad mechanical analysis including transient creep-fracture for the clad. Given the fuel pin geometry, composition and irradiation history, FEAST can analyse fuel and clad thermomechanical behaviour at both steady-state and design-basis (non-disruptive) transient scenarios. FEAST was written in FORTRAN-90 and has a simple input file similar to that of the LWR fuel code FRAPCON. The metal–fuel version is called FEAST-METAL, and is described in this paper. The oxide–fuel version, FEAST-OXIDE is described in a companion paper. With respect to the old Argonne National Laboratory code LIFE-METAL and other same-generation codes, FEAST-METAL emphasizes more mechanistic, less empirical models, whenever available. Specifically, fission gas release and swelling are modelled with the GRSIS algorithm, which is based on detailed tracking of fission gas bubbles within the metal fuel. Migration of the fuel constituents is modelled by means of thermo-transport theory. Fuel–clad chemical interaction models based on precipitation kinetics were developed for steady-state operation and transients. Finally, a transient intergranular creep-fracture model for the clad, which tracks the nucleation and growth of the cavities at the grain boundaries, was developed for and implemented in the code. Reducing the empiricism in the constitutive models should make it more acceptable to extrapolate FEAST-METAL to new fuel compositions and higher burnup, as envisioned in advanced sodium reactors. FEAST-METAL was benchmarked against the open-literature EBR-II database for steady state and furnace tests (transients). The results show that the code is able to predict important phenomena such as clad strain, fission gas release, clad wastage, clad failure time, axial fuel slug deformation and fuel constituent redistribution, satisfactorily.

11/00570 Characterization of advanced cyanate ester/epoxy insulation systems before and after reactor irradiation

Prokopec, R. *et al. Fusion Engineering and Design*, 2010, 85, (2), 227–233.

Insulation systems for fusion magnets have to operate in a harsh environment, especially also under intense radiation. In the past, cyanate ester resins have been playing an increasingly important role because of their enhanced temperature and radiation resistance compared to conventional epoxy resins. Blending cyanate ester with epoxy resins offers the possibility to manufacture radiation-resistant insulations at a low price compared to pure cyanate ester materials. Therefore, it is of special interest to study the influence of the cyanate ester content and of the epoxy resin on the mechanical properties to find materials that are suitable and economically reasonable for the specific demands of such magnets. In this study, R-glass fibre/Kapton reinforced cyanate ester/epoxy blends with different cyanate ester content were investigated. Each material was exposed to conditions matching those expected for the International Thermonuclear Experimental Reactor (ITER) TF coil insulation as closely as possible. In order to characterize the mechanical properties, short-beam shear and static tensile tests were carried out at 77 K prior to and after irradiation to fast neutron fluences of up to $5 \times 10^{22}\,m^{-2}$ ($E > 0.1$ MeV), in the TRIGA reactor (Vienna) at ambient temperature (340 K). In addition, tension–tension fatigue measurements were performed in the load-controlled mode to simulate the pulsed operation conditions of ITER.

11/00571 Characterization of high strength and high toughness Ni–Mo–Cr low alloy steels for nuclear application

Lee, B. S. *et al. International Journal of Pressure Vessels and Piping*, 2010, 87, (1), 74–80.

The reactor pressure vessels of PWRs have mostly been made of SA508 Grade 3 (Class 1) low alloy steels which have revealed moderate mechanical properties and a moderate radiation resistance for a 40 or 60 year operation. The specified minimum yield strength of the material is 345 MPa with a ductile–brittle transition temperature of about 0 °C. While other materials, most of which are non-ferrous alloys or high alloyed steels for a higher temperature application, are being developed for the Generation-4 reactors, low alloy steels with a higher strength and toughness can help to increase the safety and economy of the advanced PWR systems which will be launched in the near future. The ASME specification for SA508 Grade 4N provides a way to increase both the strength and toughness by a chemistry modification, especially by increasing the Ni and Cr contents. However, a higher strength steel has a deficiency due to a lack of operating data for nuclear power plants. In this study, experimental heats of SA508 Grade 4N steels with different chemical compositions were characterized mechanically. The preliminary results for an irradiation embrittlement and the HAZ properties are discussed in addition to their superior baseline properties.

11/00572 Considerations on fatigue stress range calculations in nuclear power plants using on-line monitoring systems and the ASME Code

Cicero, C. *et al. Nuclear Engineering and Design*, 2010, 240, (1), 47–56.

Nuclear power plants are generally designed and inspected according to the ASME Code. This code indicates stress intensity (S_{INT}) as the parameter to be used in the stress analysis of components. One of the particularities of S_{INT} is that it always takes positive values, independently of the nature of the stress (tensile or compressive). This circumstance is relevant in the fatigue monitoring systems used in nuclear power plants, due to the manner in which the different variable stresses are combined in order to obtain the final total stress range. This paper describes some situations derived from the application of the ASME Code, shows different ways of dealing with them and illustrates their influence on the evaluation of the fatigue usage factor through a case study.

11/00573 Design of a management information system for the Shielding Experimental Reactor ageing management

He, J. and Xu, X. *Nuclear Engineering and Design*, 2010, 240, (1), 103–111.

The problem of nuclear reactor ageing is a topic of increasing importance in nuclear safety recent years. Ageing management is usually implemented for reactor maintenance. In practice, a large number of data and records needs to be processed. However, there are few professional software applications that aid reactor ageing management, especially for research reactors. This paper introduces the design of a new web-based management information system (MIS), named the Shielding Experimental Reactor Ageing Management Information System (SERAMIS). It is an auxiliary means that helps to collect data, keep records, and retrieve information for a research reactor ageing management. The Java2 Enterprise Edition (J2EE) and network database techniques, such as three-tiered model, model-view-controller architecture, transaction-oriented operations, and JavaScript techniques, are used in the development of this system. The functionalities of the application cover periodic safety review, regulatory references, data inspection, and SSCs classification according to ageing manage-

ment methodology. Data and examples are presented to demonstrate the functionalities. For future work, techniques of data mining will be employed to support decision-making.

11/00574 Development of a web-based aging monitoring system for an integrity evaluation of the major components in a nuclear power plant

Choi, J.-B. *et al. International Journal of Pressure Vessels and Piping*, 2010, 87, (1), 33–40.

Structural and mechanical components in a nuclear power plant are designed to operate for its entire service life. Recently, a number of nuclear power plants are being operated beyond their design life to produce more electricity without shutting down. The critical issue in extending a lifetime is to maintain the level of safety during the extended operation period while satisfying the international regulatory standards. However, only a small portion of these components are of great importance for a significant aging degradation which would deeply affect the long-term safety and reliability of the related facilities. Therefore, it is beneficial to build a monitoring system to measure an aging status. While a number of integrity evaluation systems have been developed for NPPs, a real-time aging monitoring system has not been proposed yet. This paper proposes an expert system for the integrity evaluation of nuclear power plants based on a web-based reality environment (WRE). The proposed system provides the integrity assessment for the major mechanical components of a nuclear power plant under concurrent working environments. In the WRE, it is possible for users to understand a mechanical system such as its size, geometry, coupling condition, etc. In conclusion, it is anticipated that the proposed system can be used for a more efficient integrity evaluation of the major components subjected to an aging degradation.

11/00575 Dissolution of spent nuclear fuel in carbonate–peroxide solution

Soderquist, C. and Hanson, B. *Journal of Nuclear Materials*, 2010, 396, (2–3), 159–162.

This study shows that spent UO_2 fuel can be completely dissolved in a room temperature carbonate–peroxide solution apparently without attacking the metallic Mo–Tc–Ru–Rh–Pd fission product phase. In parallel tests, identical samples of spent nuclear fuel were dissolved in nitric acid and in an ammonium carbonate, hydrogen peroxide solution. The resulting solutions were analysed for strontium-90, technetium-99, cesium-137, europium-154, plutonium, and americium-241. The results were identical for all analytes except technetium, where the carbonate–peroxide dissolution had only about 25% of the technetium that the nitric acid dissolution had.

11/00576 Evaluating replacement project of nuclear power plants under uncertainty

Naito, Y. *et al. Energy Policy*, 2010, 38, (3), 1321–1329.

This paper investigates the valuation of a replacement project of nuclear power plants under the deregulated electricity market. The replacement project consists of two components: the decision to decommission an existing plant and the decision to construct a new plant. In the replacement project, the decommissioning decision should be made considering not only the profitability of the existing plant but also the profitability and costs of the construction of the new plant. Real options theory is used to determine the optimal timing of the decommissioning and construction. In order to examine the effect of decommissioning time and decision making one, a time-lag for these decision making times was considered. The dependence of the replacement project value on uncertainty and time-lag was shown.

11/00577 Experimental database of E110 claddings exposed to accident conditions

Perez-Feró, E. *et al. Journal of Nuclear Materials*, 2010, 397, (1–3), 48–54.

An experimental database of E110 alloy has been developed on the basis of about 600 separate and combined effect tests of the Hungarian Academy of Sciences KFKI Atomic Energy Research Institute. It contains the data of oxidation, ballooning, tensile and compression tests, the results of post-test investigations, photos, figures, information concerning the test conditions and the corresponding English-language publications. The aim of this database is to give adequate information on the E110 cladding behaviour (oxidation, hydrogen uptake, mechanical performance) under accident conditions and to provide valuable experimental data for model development and code validation. This database is a part of the International Fuel Performance Experimental Database. It is accessible on-line, via the Internet. This paper gives an overview of the experiments, the test facilities and conditions involved in the database. It presents the most important results and consequences and introduces the directory structure of the database.

11/00578 Factoring-based method for the design of a nuclear fuel

Guzmán-Arriaga, R. and Espinosa-Paredes, G. *Energy Conversion and Management*, 2010, 51, (5), 918–927.

In this work a simple method for a fuel lattice design is presented. The method is focused on finding the radial distribution of the fuel rods having different fissile contents to obtain a prescribed neutron multiplication factor k_∞ to a certain discharge burnup and to minimize the rod power peaking. This method is based on the factorization of the fissile content of each fuel bar and the performance of this novel method was demonstrated with a fuel design composed of enriched uranium for a typical boiling water reactor. The results show that the factoring-based method for the design of a nuclear fuel converges to a minimum rod power peaking and a prescribed k_∞ in few iterations. A comparative analysis shows that the proposed method is more efficient than existing methods.

11/00579 Impact of auto-irradiation on the thermophysical properties of oxide nuclear reactor fuels

Staicu, D. *et al. Journal of Nuclear Materials*, 2010, 397, (1–3), 8–18.

The effect of α-damage on the thermophysical properties of UO_2 was investigated using samples doped with ^{238}Pu. Characterizations were performed after different storage periods, including X-ray diffraction to monitor the lattice parameter evolution, Knudsen-cell helium release experiments and transmission electron microscopy examinations. The apparent heat capacity was measured by differential scanning calorimetry and the recovery stages observed were attributed to the recombination of a certain kind of point or extended defect. The thermal diffusivity, measured by the laser-flash technique during annealing cycles, displayed similar recovery stages. The measurements show that the degradation of the diffusivity with increasing α-dose is not linear, and that saturation occurs at relatively low doses. A correlation quantifying this degradation is proposed. Comparison with the thermal diffusivity of very low burn-up rector irradiated samples, where the main source of degradation is radiation damage, shows that the annealing stages are similar.

11/00580 Interpretation and modelling of fission product Ba and Mo releases from fuel

Brillant, G. *Journal of Nuclear Materials*, 2010, 397, (1–3), 40–47.

The release mechanisms of two fission products (namely barium and molybdenum) in severe accident conditions are studied using the VERCORS experimental observations. Barium is observed to be mostly released under reducing conditions while molybdenum release is most observed under oxidizing conditions. As well, the volatility of some precipitates in fuel is evaluated by thermodynamic equilibrium calculations. The polymeric species $(MoO_3)n$ are calculated to largely contribute to molybdenum partial pressure and barium volatility is greatly enhanced if the gas atmosphere is reducing. Analytical models of fission product release from fuel are proposed for barium and molybdenum. Finally, these models have been integrated in the ASTEC/ELSA code and validation calculations have been performed on several experimental tests.

11/00581 Numerical analysis of hydrogen risk mitigation measures for support of ITER licensing

Xiao, J. *et al. Fusion Engineering and Design*, 2010, 85, (2), 205–214.

In the International Thermonuclear Experimental Reactor (ITER) wet bypass scenario, water leakage, air ingress and hot dust (Be, W, and C) in the vacuum vessel could generate combustible hydrogen–air–steam mixture. Hydrogen combustion may threaten the integrity of the ITER VV and lead to radioactivity release. To prevent hydrogen energetic combustion, nitrogen injection system in VV and hydrogen recombination system in the pressure suppression tank (ST) were proposed. The main objectives of this analysis are to study the distribution of hydrogen–air–steam mixtures in the ITER sub-volumes, to investigate the feasibility of the nitrogen injection system to fully inert the atmosphere in the VV and to evaluate the capability and efficiency of the hydrogen recombination system to remove hydrogen in the ST. The three-dimensional computational fluid dynamics code GASFLOW was used to calculate the evolution of the mixtures and to evaluate the hydrogen combustion risks in the ITER sub-volumes. The results indicate that the proposed hydrogen risk mitigation systems will generally prevent the risks of hydrogen detonation and fast deflagration. However, the atmosphere in ITER sub-volumes cannot be completely inerted at the early stage of the scenario. Slow deflagrations could still generate quasi-static pressures above 1 bar in the VV. The structural impact of the thermal and pressure loads generated by hydrogen combustions will be investigated in future studies.

11/00582 Overview of statistical models of fracture for nonirradiated nuclear-graphite components

Nemeth, N. N. and Bratton, R. L. *Nuclear Engineering and Design*, 2010, 240, (1), 1–29.

Nuclear-grade (low-impurity) graphite for the fuel element and moderator material for next generation (Gen IV) reactors displays large scatter in strength and a non-linear stress–strain response from damage accumulation. This response can be characterized as quasi-brittle. In this review, relevant statistical failure models for various brittle and quasi-brittle material systems are discussed with regard to strength distribution, size effect, multiaxial strength, and damage accumulation. This includes descriptions of the Weibull, Batdorf, and Burchell models as well as models that describe the strength response of composite materials, which involves distributed damage. Results from lattice simulations are included for a physics-based description of material breakdown. Consideration is given to the predicted transition between brittle and quasi-brittle damage behaviour versus the density of damage (level of disorder) within the material system. The literature indicates that weakest-link-based failure modelling approaches appear to be reasonably robust in that they can be applied to materials that display distributed damage, provided that the level of disorder in the material is not too large. The Weibull distribution is argued to be the most appropriate statistical distribution to model the stochastic strength response of graphite.

11/00583 Possibility of ultra-intense laser transmutation of ^{93}Zr (γ, n) ^{92}Zr a long-lived nuclear waste into a stable isotope

Sadighi-Bonabi, R. *et al. Energy Conversion and Management*, 2010, 51, (4), 636–639.

The possibility of photonuclear transmutation of ^{93}Zr, a highly radioactive nuclear waste with a half-life of 1.53 million years, into ^{92}Zr its stable isotope, through a (γ, n) reaction has been analytically evaluated in this paper. By focusing intensities more than 10^{20} W/cm^2 onto a solid target, high energy electron generation, Bremsstrahlung and photonuclear reactions have been observed. Using the available data, the number of reactions that produced ^{92}Zr, have been analytically calculated. In addition, this work has shown that the laser intensity, irradiation time and repetition rate of laser have strong and direct effects on the yield of ^{92}Zr and the number of reactions. Irradiating a ^{93}Zr sample by a laser with the intensity of 10^{21} W/cm^2 and 5×10^{21} W/cm^2, and the repetition rate of 10 Hz for an hour, the number of reactions obtained are, 1.44×10^6 and 4.38×10^7, respectively. Finally, the authors evaluate the optimal intensity of laser to produce the maximum number of reactions. However, beyond the optimal intensity, this effect is very slow.

11/00584 Resolving the H_2 effect on radiation induced dissolution of UO_2-based spent nuclear fuel

Trummer, M. and Jonsson, M. *Journal of Nuclear Materials*, 2010, 396, (2–3), 163–169.

In recent years, the impact of H_2 on α-radiation induced dissolution of UO_2-based spent nuclear fuel has been studied and debated extensively. Experimental results on the effect of H_2 on the concentration of H_2O_2 during α-radiolysis have been shown to disagree with numerical simulations. For this reason, the reaction scheme used in simulations of aqueous radiation chemistry has sometimes been questioned. In this work, the impact of H_2 on the H_2O_2 concentration in α-irradiated aqueous solution using numerical simulations is studied. The effects of H_2 pressure, α-dose rate and HCO_3^- concentration were investigated by performing systematic variations in these parameters. The simulations show that the discrepancy between the previously published experimental result and numerical simulations is due to the use of a homogeneous dose rate (the energy is assumed to be equally distributed in the whole volume). Taking the actual dose rate of the α-irradiated volume into account, the simulation is in perfect agreement with the experimental results. This shows that the H_2 effect is strongly α-dose rate dependent, and proves the reliability of the reaction scheme used in the simulations. The simulations also show that H_2 influences the H_2O_2 concentration under α-radiolysis. The magnitude of the effect depends on the dose rate and the H_2 pressure as well as on the concentration of HCO_3^-. The impact of the radiolytic H_2 effect on the rate of α-radiation induced dissolution of spent nuclear fuel is discussed along with other (α- and γ-) radiation induced processes capable of reducing the concentration of uranium in solution. The radiolytic H_2 effect is quantitatively compared to the previously presented noble metal catalysed H_2 effect. This comparison shows that the noble metal catalysed H_2 effect is far more efficient than the radiolytic H_2 effect. Reduction of U(VI) in solution due to low dose rate γ-radiolysis in the presence of H_2 is proposed to be the cause of the H_2 effect observed in leaching experiments on α-doped UO_2.

11/00585 Service-oriented architecture of adaptive, intelligent data acquisition and processing systems for long-pulse fusion experiments

González, J. *et al. Fusion Engineering and Design*, 2010, 85, (3–4), 274–279.

The data acquisition systems used in long-pulse fusion experiments need to implement data reduction and pattern recognition algorithms in real time. In order to accomplish these operations, it is essential to employ software tools that allow for hot swap capabilities throughout the temporal evolution of the experiments. This is very important because processing needs are not equal during different phases of the experiment. The intelligent test and measurement system (ITMS) developed by UPM and CIEMAT is an example of a technology for implementing scalable data acquisition and processing systems based on PXI and CompactPCI hardware. In the ITMS platform, a set of software tools allows the user to define the processing algorithms associated with the different experimental phases using state machines driven by software events. These state machines are specified using the State Chart XML (SCXML) language. The software tools are developed using JAVA, JINI, an SCXML engine and several LabVIEW applications. Within this schema, it is possible to execute data acquisition and processing applications in an adaptive way. The power of SCXML semantics and the ability to work with XML user-defined data types allow for very easy programming of the ITMS platform. With this approach, the ITMS platform is a suitable solution for implementing scalable data acquisition and processing systems based on a service-oriented model with the ability to easily implement remote participation applications.

11/00586 Simulation and high performance computing – building a predictive capability for fusion

Strand, P. I. *et al. Fusion Engineering and Design*, 2010, 85, (3–4), 383–387.

The Integrated Tokamak Modelling Task Force (ITM-TF) is developing an infrastructure where the validation needs, as being formulated in terms of multi-device data access and detailed physics comparisons aiming for inclusion of synthetic diagnostics in the simulation chain, are key components. As the activity and the modelling tools are aimed for general use, although focused on International Thermonuclear Experimental Reactor (ITER) plasmas, a device-independent approach to data transport and a standardized approach to data management (data structures, naming, and access) is being developed in order to allow cross-validation between different fusion devices using a single toolset. Extensive work has already gone into, and is continuing to go into, the development of standardized descriptions of the data (consistent physical objects). The longer term aim is a complete simulation platform which is expected to last and be extended in different ways for the coming 30 years. The technical underpinning is therefore of vital importance. In particular the platform needs to be extensible and open-ended to be able to take full advantage of not only today's most advanced technologies but also be able to marshal future developments. As a full level comprehensive prediction of ITER physics rapidly becomes expensive in terms of computing resources, the simulation framework needs to be able to use both grid and HPC computing facilities. Hence data access and code coupling technologies are required to be available for a heterogeneous, possibly distributed, environment. The developments in this area are pursued in a separate project – EUFORIA (EU Fusion for ITER Applications) which is providing about 15 professional-persons-year (ppy) per annum from 14 different institutes. The range and size of the activity is not only technically challenging but is providing some unique management challenges in that a large and geographically distributed team (a truly pan-European set of researchers) need to be coordinated on a fairly detailed project level. The 2009 work programme of ITM-TF organized 240 individuals from 24 different associations providing about 60 ppy in total. Remote participation and collaborative tools and facilities as the ENEA sponsored gateway have proven indispensable to meet this challenge. The current status of ITM-TF and EUFORIA is presented and discussed.

11/00587 Time accuracy requirements for fusion experiments: a case study at ASDEX upgrade

Raupp, G. *et al. Fusion Engineering and Design*, 2010, 85, (3–4), 356–359.

To manage and operate a fusion device and measure meaningful data an accurate and stable time is needed. As a benchmark, the authors suggest to consider time accuracy as sufficient if it is better than typical data errors or process timescales. This allows one to distinguish application domains and chose appropriate time distribution methods. For ASDEX Upgrade a standard NTP method provides Unix time for project and operation management tasks, and a dedicated time system generates and distributes a precise experiment time for physics applications. Applying the benchmark to ASDEX upgrade shows that physics measurements tagged with experiment time meet the requirements, while correlation of NTP tagged operation data with physics data tagged with experiment time remains problematic. Closer coupling of the two initially free running time systems with daily re-sets was an efficient and satisfactory improvement. For ultimate accuracy and

seamless integration, however, continuous adjustment of the experiment time clock frequency to NTP is needed, within frequency variation limits given by the benchmark.

Economics, policy, supplies, forecasts

11/00588 A proposal for the ITER remote participation system in Japan

Nagayama, Y. *et al. Fusion Engineering and Design*, 2010, 85, (3–4), 535–539.

This paper presents a proposal of the remote participation system for the International Thermonuclear Experimental Reactor (ITER). The object of this paper is to clarify technical issues to analyse the ITER data safely and conveniently. The Japanese case is considered as an example, but technologies presented here can be used worldwide. Major technical issues are as follows: (1) the long distance data transfer; (2) the massive data server; (3) the secure network; (4) the convenient and fast data analysis system. Raw data of ITER can be transferred from France to Japan in a short time by optimizing TCP/IP parameters. The virtual private network (VPN) technology provides a secure environment of the data mirroring and the distributed computation. The analysis server with a web user interface enables physicists to analyse ITER data over the Internet. Streaming data, such as plasma parameters in the steady state, video and sound of the ITER plasma and the status of experiment, which provides feeling of reality, are delivered by using the multi-cast technology. These technologies are being developed in SNET, which is a virtual laboratory for Japanese fusion community. International collaboration is required to develop a global distributed file system and a data analysis system further.

11/00589 A study of the probabilistic risk assessment to the dry storage system of spent nuclear fuel

Chen, K. C. *et al. International Journal of Pressure Vessels and Piping*, 2010, 87, (1), 17–25.

Due to the large power supply in the energy market since 1960s, the nuclear power planets have been consistently constructed throughout the world in order to maintain and supply sufficient fundamental power generation. Up to now, most of the plants have been operated to a point where the spent fuel pool has reached its design capacity volume. To prevent the plant from shutdown due to the spent fuel pool exceeding the design capacity, the dry cask storage can provides a solution for both the spent fuel pool capacity and the mid-term storage method for the spent fuel bundles at nuclear power planet. Currently, the dry cask storage system and relevant operating procedures have also gradually been deployed and consistently developed in order to facilitate the dry storage for the spent fuel bundles. In other words, spent fuel bundles dry storage and its safety has become an important issue and will directly affect the smooth operation of the plants once the spent fuel pool reaches its design capacity. Plants in the United States, Nuclear Regulatory Commission, the Office of Nuclear Material Safety and Safeguards (NMSS), the Office of Nuclear Regulatory Research (RES) and Spent Fuel Project Office (NMSS) have jointly developed a pilot methodology for probabilistic risk assessments. Adopting quantitative and qualitative evaluating methods to the subject BWR plants based on the handling, transfer and storage three phases. Obtaining the annual risk for one cask in terms of the individual probability of a prompt fatality within 1.6 km and a latent cancer fatality within 16 km can provide useful risk information for the subject BWR plant. This pilot study used NUREG-1864, 'A Pilot Probabilistic Risk Assessment of a Dry Cask Storage System at a Nuclear Power Planet', related generic data and built prototype models for risk assessments in Taiwan nuclear power plants. This pilot study investigated the handling, transfer and storage three phases to establish its risk evaluating methodologies, which includes initialing events, failure probabilities for canister and cask under mechanical loads and proceeded risk assessment for all three phases using quantitative fault tree analysis. The results of this study can be as a reference for future more detailed developments of the dry cask storage system risk assessments at Taiwan nuclear power plants.

11/00590 An investigation of secure remote instrument control

Schissel, D. P. *et al. Fusion Engineering and Design*, 2010, 85, (3–4), 608–613.

This paper examines the computer science issues associated with secure remote instrumentation control for magnetic fusion experiments. Computer science research into enhancing the ability to scientifically participate in a fusion experiment remotely has been growing in size in an attempt to better address the needs of fusion scientists worldwide. The natural progression of this research is to examine how to move from remote scientific participation to remote hardware control. The vision is to define a gatekeeper software system that will be the only channel of interaction for incoming requests to the secured area of the experimental site. The role of the gatekeeper is to validate the identification and access privilege of the requestor and to insure the general validity of the proposed request. The vision for the gatekeeper is that it be a modular system that is simple in design and defined in a way that makes its implementation and operation transparent and obvious. The architecture of the module interface is flexible enough that it can easily allow the future addition of new modules. At the same time, it should be transparent to end-users and allow a high volume of activity so as to not provide a work bottleneck. The results of the gatekeeper design and initial implementation are presented as well as a discussion on the implication of this research on the operation of fusion experimental machines such as ITER.

11/00591 Customizable scientific web portal for fusion research

Abla, G. *et al. Fusion Engineering and Design*, 2010, 85, (3–4), 603–607.

Web browsers have become a major application interface for participating in scientific experiments such as those in magnetic fusion. The recent advances in web technologies motivated the deployment of interactive web applications with rich features. In the scientific world, web applications have been deployed in portal environments. When used in a scientific research environment, such as fusion experiments, web portals can present diverse sources of information in a unified interface. However, the design and development of a scientific web portal has its own challenges. One such challenge is that a web portal needs to be fast and interactive despite the high volume of information and number of tools it presents. Another challenge is that the visual output of the web portal must not be overwhelming to the end users, despite the high volume of data generated by fusion experiments. Therefore, the applications and information should be customizable depending on the needs of end users. In order to meet these challenges, the design and implementation of a web portal needs to support high interactivity and user customization. A web portal has been designed to support the experimental activities of DIII-D researchers worldwide by providing multiple services, such as real-time experiment status monitoring, diagnostic data access and interactive data visualization. The web portal also supports interactive collaborations by providing a collaborative logbook, shared visualization and online instant messaging services. The portal's design utilizes the multi-tier software architecture and has been implemented utilizing web 2.0 technologies, such as AJAX, Django, and Memcached, to develop a highly interactive and customizable user interface. It offers a customizable interface with personalized page layouts and list of services, which allows users to create a unique, personalized working environment to fit their own needs and interests. This paper describes the software architecture of this scientific web portal and its implementation to include deployment experiences during the 2009 DIII-D experimental campaign.

11/00592 Measuring the social value of nuclear energy using contingent valuation methodology

Jun, E. *et al. Energy Policy*, 2010, 38, (3), 1470–1476.

As one of the promising energy sources for the next few decades, nuclear energy receives more attention than before as environmental issues become more important and the supply of fossil fuels becomes unstable. One of the reasons for this attention is based on the rapid innovation of nuclear technology which solves many of its technological constraints and safety issues. However, regardless of these rapid innovations, social acceptance for nuclear energy has been relatively low and unchanged. Consequently, the social perception has often been an obstacle to the development and execution of nuclear policy requiring enormous subsidies which are not based on the social value of nuclear energy. Therefore, in this study the social value of nuclear energy-consumers' willingness-to-pay for nuclear energy – using the contingent valuation method was estimated, leading to the suggestion that the social value of nuclear energy increases approximately 68.5% with the provision of adequate information about nuclear energy to the public. Consequently, it was also suggested that the social acceptance management is important along with nuclear technology innovation.

11/00593 Multiobjective genetic algorithm strategies for electricity production from generation IV nuclear technology

Gomez, A. *et al. Energy Conversion and Management*, 2010, 51, (4), 859–871.

Development of a technico-economic optimization strategy of cogeneration systems of electricity/hydrogen, consists in finding an optimal efficiency of the generating cycle and heat delivery system, maximizing the energy production and minimizing the production costs. The first part of the paper is related to the development of a multiobjective optimization library (MULTIGEN) to tackle all types of problems arising from cogeneration. After a literature review for identifying the most efficient methods, the MULTIGEN library is described, and the

innovative points are listed. A new stopping criterion, based on the stagnation of the Pareto front, may lead to significant decrease of computational times, particularly in the case of problems involving only integer variables. Two practical examples are presented in the last section. The former is devoted to a bicriteria optimization of both exergy destruction and total cost of the plant, for a generating cycle coupled with a very high temperature reactor. The second example consists in designing the heat exchanger of the generating turbomachine. Three criteria are optimized: the exchange surface, the exergy destruction and the number of exchange modules.

11/00594 Reference stress method for evaluation of failure assessment curve of cracked pipes in nuclear power plants
Kamaya, M. and Machida, H. *International Journal of Pressure Vessels and Piping*, 2010, 87, (1), 66–73.
In order to obtain a precise failure assessment curve (FAC) in the R6 defect assessment procedure, it is necessary to evaluate the J-value of cracked components. The reference stress method can be used for estimating J-values. However, the accuracy of estimation depends on the limit load used for evaluating the reference stress. In this study, the applicability of several limit load solutions was investigated through comparison with the results of elastic-plastic finite element analyses (FEA). A pipe containing a circumferential surface crack was analysed under pure bending load. Six materials used in nuclear power plants were assumed. It was shown that the reference stress method is valid for FAC evaluation. The maximum non-conservativeness caused by using the reference stress method is less than 20% compared to the results obtained by FEA.

11/00595 Safety assessment for the passive system of the nuclear power plants (NPPs) using safety margin estimation
Woo, T. H. and Lee, U.-C. *Energy*, 2010, 35, (4), 1799–1804.
The probabilistic safety assessment for gas-cooled nuclear power plants has been investigated where the operational data are deficient, because there is not any commercial gas-cooled nuclear power plant. Therefore, it is necessary to use the statistical data for the basic event constructions. Several estimations for the safety margin are introduced for the quantification of the failure frequency in the basic event, which is made by the concept of the impact and affordability. Trend of probability of failure and fuzzy converter are introduced using the safety margin, which shows the simplified and easy configurations for the event characteristics. The mass flow rate in the natural circulation is studied for the modelling. The potential energy in the gravity, the temperature and pressure in the heat conduction, and the heat transfer rate in the internal stored energy are also investigated. The values in the probability set are compared with those of the fuzzy set modelling. Non-linearity of the safety margin is expressed by the fuzziness of the membership function. This artificial intelligence analysis of the fuzzy set could enhance the reliability of the system comparing to the probabilistic analysis.

11/00596 Study of ultimate seismic response and fragility evaluation of nuclear power building using nonlinear three-dimensional finite element model
Nakamura, N. *et al. Nuclear Engineering and Design*, 2010, 240, (1), 166–180.
The probabilistic safety assessment (PSA) is important for nuclear power buildings in Japan because the risk of the occurrence of seismic ground motions beyond the design assumption cannot be denied. In this paper, the building fragility of the seismic PSA was evaluated using a high accuracy analysis model (three-dimensional non-linear finite element method building model considering soil–structure interaction and basemat uplift behaviour). First, the response analyses were conducted increasing the input acceleration up to 3500 Gal, until the damage of the building reached the ultimate condition. The damage of the building was estimated from the shear strain, the axial stress, and the consumed strain energy of the shear walls. Then, the influence on the response given by the vertical ground motion and the basemat uplift was evaluated. In addition, considering the shear destruction of the web wall and compressive crash of the flange wall as the fracture modes, the building fragility was evaluated. As a result, it was shown that the investigated method is efficient for more accurate seismic PSA estimation.

11/00597 Sustainability issues in the development of nuclear fission energy
Piera, M. *Energy Conversion and Management*, 2010, 51, (5), 938–946.
A review is made of the ongoing lines of R&D in the field on nuclear fission and potential alternatives based on specific features of some types of reactors. This nuclear perspective is confronted with a proposal on sustainability criteria for the nuclear fission field. This proposal stems from an analysis of the main drawbacks of nuclear fission, notably those related to security, safety and environment. On the other hand, it is pointed out that nuclear fission is a sound and proven CO_2-free source of energy, with an outstanding maturity in its current stage of commercial development, and with an enormous potential to undergo new phases of industrial developments by exploiting very appealing features of the nuclear phenomenology, which deserve further research, under the guidance of sustainability concepts and criteria.

11/00598 The ITER safety control systems – status and plans
Scibile, L. *et al. Fusion Engineering and Design*, 2010, 85, (3–4), 540–544.
The operation of a complex experimental machine like the International Thermonuclear Experimental Reactor (ITER) will involve a number of potential hazards to personnel, the environment, and to the machine itself. While some protections are usually embedded within the overall control system, when it comes to the protection of people, the environment or the safe operation of the machine, dedicated systems are required. At ITER, the safety control systems are dedicated to the protection of people and the environment. These systems represents one of the three independent tiers on which the ITER instrumentation and control is based. They have to respect stringent requirements in terms of reliability, availability, safety and maintainability for operation, security and national and/or international safety regulations. This paper describes the current status and plans of the safety control systems, the functions to be performed, the envisaged architecture and the main design options including the principles of separation and independence between the three tiers.

11/00599 Using SharePoint to manage and disseminate fusion project information: an ITER case study
Prescott, B. *et al. Fusion Engineering and Design*, 2010, 85, (3–4), 571–578.
The International Thermonuclear Experimental Reactor (ITER) organization, in common with many other fusion laboratories, has an authenticated-access website devoted to the communication of information to all its staff and remote collaborators. In 2007 and 2008, the number of registered users of this site increased by more than a factor of ten, to over 3000, and with approximately 900 unique users using the website per month. In parallel, the project management of the organization has been put in place. A decision was taken to move the web platform from simple HTML to Microsoft SharePoint and to web-enable the many applications and databases used for ITER management. This decision has been well justified by the power and extensive flexibility provided by SharePoint, for example, it permits different groups to publish their own information and to collaborate, and to consolidate disparate spreadsheet data in linked SharePoint lists to improve quality and maintainability. This paper examines the use of SharePoint at ITER, why it was selected and what benefits it brings to both the local and remote ITER community. Some active case studies are presented. The paper also looks ahead at what future benefits to ITER this platform offers, and reviews the type of information that the site can profitably publish. The paper also highlights some of the limitations of the platform, the problems of integration with other ITER systems, and discusses its potential for adaptability in other scientific organixations.

06 ELECTRICAL POWER SUPPLY AND UTILIZATION

Scientific, technical

11/00600 A new fuzzy adaptive particle swarm optimization for non-smooth economic dispatch
Niknam, T. *et al. Energy*, 2010, 35, (4), 1764–1778.
This paper proposes a novel method for solving the non-convex economic dispatch (NED) problems, by the fuzzy adaptive modified particle swarm optimization (FAMPSO). Practical ED problems have non-smooth cost functions with equality and inequality constraints when generator valve-point loading effects are taken into account. Modern heuristic optimization techniques have been given much attention by many researchers due to their ability to find an almost global optimal solution for ED problems. PSO is one of modern heuristic algorithms, in which particles change place to get close to the best position and find the global minimum point. However, the classic PSO may converge to a local optimum solution and the performance of

the PSO highly depends on the internal parameters. To overcome these drawbacks, in this paper, a new mutation is proposed to improve the global searching capability and prevent the convergence to local minima. Also, a fuzzy system is used to tune its parameters such as inertia weight and learning factors. In order to evaluate the performance of the proposed algorithm, it is applied to a system consisting of 13 and 40 thermal units whose fuel cost function is calculated by taking account of the effect of valve-point loading. Simulation results demonstrate the superiority of the proposed algorithm compared to other optimization algorithms presented in literature.

11/00601 Accurate fault location algorithm for transmission line in the presence of series connected FACTS devices

Sadeh, J. and Adinehzadeh, A. *International Journal of Electrical Power & Energy Systems*, 2010, 32, (3), 323–328.

This paper presents a new and accurate fault location algorithm based on distributed time domain line model for a transmission line compensated with series connected FACTS device. In the proposed algorithm, in order to compute the voltage drop across the series device during the fault period, the series device model and knowledge about the operating mode of the compensating device are not utilized. For this reason, the proposed technique can be easily applied to any series FACTS compensated line. Samples of voltage and current at both ends of the line are taken synchronously and used to calculate the location and resistance of the fault. The proposed algorithm is not sensitive to fault resistance and fault inception angle and does not require any knowledge of equivalent source impedances. This method has been tested using EMTP/ATP model of a 400 kV, 300 km transmission line compensated with a series FACTS device. The results of computer simulations for different operating conditions demonstrate the very high accuracy and robustness of the algorithm.

11/00602 Combined modeling for electric load forecasting with adaptive particle swarm optimization

Wang, J. *et al. Energy*, 2010, 35, (4), 1671–1678.

Electric load forecasting is crucial for managing electric power systems economically and safely. This paper presents a new combined model for electric load forecasting based on the seasonal ARIMA forecasting model, the seasonal exponential smoothing model and the weighted support vector machines. The combined model can effectively count for the seasonality and nonlinearity shown in the electric load data and give more accurate forecasting results. The adaptive particle swarm optimization is employed to optimize the weight coefficients in the combined forecasting model. The proposed combined model has been compared with the individual models and the other combined model reported in the literature and its results are promising.

11/00603 Comparative analysis of techniques for control of switching overvoltages during transmission lines energization

Mestas, P. and Tavares, M. C. *Electric Power Systems Research*, 2010, 80, (1), 115–120.

The energization of long transmission lines can cause high overvoltage stresses not only along the transmission line, but also in the rest of the network. The traditional method of limiting switching overvoltages to acceptable levels is the use of circuit breakers equipped with pre-insertion resistors. The present paper describes a study comparing this traditional method with two other alternatives for the limitation of switching overvoltages during line energization in an actual 500 kV transmission system: the use of metal oxide surge arresters at both line closing of circuit breaker poles. Digital simulations were made with PSCAD/EMTDC software and the degree of shunt compensation is considered as an independent parameter.

11/00604 Decentralised optimisation of cogeneration in virtual power plants

Wille-Haussmann, B. *et al. Solar Energy*, 2010, 84, (4), 604–611.

Within several projects grid structures and management strategies were investigated for active grids with high penetration of renewable energy resources and distributed generation (RES & DG). Those 'smart grids' should be designed and managed by model-based methods, which are elaborated within these projects. Cogeneration plants (CHP) can reduce the greenhouse gas emissions by locally producing heat and electricity. The integration of thermal storage devices is suitable to get more flexibility for the cogeneration operation. If several power plants are bound to centrally managed clusters, it is called 'virtual power plant'. There is a great potential for the optimized management of CHPs, which is not yet used. Due to the fact that electrical and thermal demands do not occur simultaneously, a thermally driven CHP cannot supply electrical peak loads when needed. With the usage of thermal storage systems it is possible to decouple electric and thermal production. An optimization method was developed based on mixed integer linear programming (MILP) for the management of local heat supply systems with CHPs, heating boilers and thermal storages. The algorithm allows the production of thermal and electric energy with a maximal benefit. In addition to fuel and maintenance costs it is assumed that the produced electricity of the CHP is sold at dynamic prices. This developed optimization algorithm was used for an existing local heat system with 5 CHP units of the same type. An analysis of the potential showed that about 10% increase in benefit is possible compared to a typical thermally driven CHP system under current German boundary conditions. The quality of the optimization result depends on an accurate prognosis of the thermal load which is realized with an empiric formula fitted with measured data by a multiple regression method. The key functionality of a virtual power plant is to increase the value of the produced power by clustering different plants. The first step of the optimization concerns the local operation of the individual power generator, the second step is to calculate the contribution to the virtual power plant. With small extensions the suggested MILP algorithm can be used for an overall EEX (European Energy Exchange) optimized management of clustered CHP systems in form of the virtual power plant. This algorithm has been used to control cogeneration plants within a distribution grid.

11/00605 Design, construction, and ocean testing of a taut-moored dual-body wave energy converter with a linear generator power take-off

Elwood, D. *et al. Renewable Energy*, 2010, 35, (2), 348–354.

This paper presents an overview of the SeaBeavI project which began in the fall of 2006 and culminated in the ocean testing of a 10 kW direct-drive wave energy conversion system in the fall of 2007. The SeaBeavI project was an interdisciplinary effort bringing together researchers from electrical, mechanical, and ocean engineering. A systems design approach was used to develop the taut-moored dual-body wave energy converter concept with the detailed design focused on production and ease of maintenance.

11/00606 Electricity generation from synthetic substrates and cheese whey using a two chamber microbial fuel cell

Antonopoulou, G. *et al. Biochemical Engineering Journal*, 2010, 50, (1–2), 10–15.

In this study, the possibility of electricity generation from diluted cheese whey in a two-chamber mediator-less microbial fuel cell (MFC) was investigated. Synthetic substrates such as glucose and lactose were also used for characterization of the MFC and for microbial acclimation at the anode compartment. The maximum power density obtained using diluted cheese whey was 18.4 mW/m^2 (normalized to the geometric area of the anodic electrode, which was 13.8 cm^2), corresponding to a current density of 80 mA/m^2 and a MFC voltage of 0.23 V. The coulombic efficiency ε_{cb} was very low (only 1.9%), implying that a pretreatment step of raw cheese whey is essential prior to use. For comparison, in the case of sugars (glucose and lactose) the obtained maximum power density was 15.2 mW/m^2 with ε_{cb} equal to 28% for glucose and 17.2 mW/m^2 with ε_{cb} equal to 22% for lactose. Impedance spectroscopy measurements showed that the dominant contribution to the cell overpotential was due to the ohmic resistance of the MFC. The contribution of the electrode overpotentials was also significant, mainly that of the cathode overpotential.

11/00607 High-efficiency grid-connected photovoltaic module integrated converter system with high-speed communication interfaces for small-scale distribution power generation

Choi, W.-Y. and Lai, J.-S. *Solar Energy*, 2010, 84, (4), 636–649.

This paper presents a high-efficiency grid-connected photovoltaic (PV) module integrated converter (MIC) system with reduced PV current variation. The proposed PV MIC system consists of a high-efficiency step-up DC–DC converter and a single-phase full-bridge DC–AC inverter. An active-clamping flyback converter with a voltage-doubler rectifier is proposed for the step-up DC–DC converter. The proposed step-up DC–DC converter reduces the switching losses by eliminating the reverse-recovery current of the output rectifying diodes. To reduce the PV current variation introduced by the grid-connected inverter, a PV current variation reduction method is also suggested. The suggested PV current variation reduction method reduces the PV current variation without any additional components. Moreover, for centralized power control of distributed PV MIC systems, a PV power control scheme with both a central control level and a local control level is presented. The central PV power control level controls the whole power production by sending out reference power signals to each individual PV MIC system. The proposed step-up DC–DC converter achieves a high-efficiency of 97.5% at 260 W output power to generate the DC-link voltage of 350 V from the PV voltage of 36.1 V. The PV MIC system including the DC–DC converter and the DC–AC inverter achieves a high-efficiency of 95% with the PV current ripple less than 3% variation of the rated PV current.

11/00608 Low temperature and moisture effects on polarization and depolarization currents of oil-paper insulation

Fofana, I. *et al. Electric Power Systems Research*, 2010, 80, (1), 91–97.
In past decades, dielectric testing techniques have been used and investigated as potential tools for condition assessment of oil-paper insulation. From fields and laboratory investigations these techniques were found to be highly dependent on the operating conditions (moisture, ageing, temperature, etc.). Because field measurements (generally performed after de-energizing the transformer), last hours after de-energizing the transformer, the ambient temperature may affect the results. Especially in cold regions of the world, extreme care is required to interpret the results when performing tests at surrounding low temperatures. A better understanding and analysis of the dielectric test results are therefore only possible with a clear understanding of the physical behaviour of the insulation system in response to the ambient conditions. In the current research project, a series of experiments have been performed under controlled laboratory conditions with preset moisture content inside the insulation. This paper reports the effects of low temperature on the time domain dielectric response of oil-impregnated paper insulation.

11/00609 Metamodel-assisted evolutionary algorithms for the unit commitment problem with probabilistic outages

Georgopoulou, C. A. and Giannakoglou, K. C. *Applied Energy*, 2010, 87, (5), 1782–1792.
An efficient method for solving power generating unit commitment (*UC*) problems with probabilistic unit outages is proposed. It is based on a two-level evolutionary algorithm (*EA*) minimizing the expected total operating cost (*TOC*) of a system of power generating units over a scheduling period, with known failure and repair rates of each unit. To compute the cost function value of each *EA* population member, namely a candidate *UC* schedule, a Monte Carlo simulation must be carried out. Some thousands of replicates are generated according to the units' outage and repair rates and the corresponding probabilities. Each replicate is represented by a series of randomly generated availability and unavailability periods of time for each unit and the *UC* schedule under consideration accordingly. The expected *TOC* is the average of the *TOCs* of all Monte Carlo replicates. Therefore, the *CPU* cost per Monte Carlo evaluation increases noticeably and so does the *CPU* cost of running the *EA*. To reduce it, the use of a metamodel-assisted *EA* (*MAEA*) with on-line trained surrogate evaluation models or metamodels (namely, radial-basis function networks) is proposed. A novelty of this method is that the metamodels are trained on a few 'representative' unit outage scenarios selected among the Monte Carlo replicates generated once during the optimization and, then, used to predict the expected *TOC*. Based on this low cost, approximate pre-evaluation, only a few top individuals within each generation undergo Monte Carlo simulations. The proposed *MAEA* is demonstrated on test problems and shown to drastically reduce the *CPU* cost, compared to *EAs* which are exclusively based on Monte Carlo simulations.

11/00610 National and regional generation of municipal residue biomass and the future potential for waste-to-energy implementation

Gregg, J. S. *Biomass and Bioenergy*, 2010, 34, (3), 379–388.
Municipal residue biomass (MRB) in the municipal solid waste (MSW) stream is a potential year-round bioenergy feedstock. A method is developed to estimate the amount of residue biomass generated by the end-user at the scale of a country using a throughput approach. Given the trade balance of food and forestry products, the amount of MRB generated is calculated by estimating product lifetimes, discard rates, rates of access to MSW collection services, and biomass recovery rates. A wet tonne of MRB could be converted into about 8 GJ of energy and 640 kg of carbon dioxide (CO_2) emissions, or buried in a landfill where it would decompose into 1800 kg of CO_2 equivalent (in terms of global warming potential) methane (CH_4) and CO_2 emissions. It is estimated that approximately 1.5 Gt y^{-1} of MRB are currently collected worldwide. The energy content of this biomass is approximately 12 EJ, but only a fraction is currently utilized. An integrated assessment model is used to project future MRB generation and its utilization for energy, with and without a hypothetical climate policy to stabilize atmospheric CO_2 concentrations. Given an anticipated price for biomass energy (and carbon under a policy scenario), by the end of the century, it is projected that nearly 60% of global MRB would be converted to about 8 EJ y^{-1} of energy in a reference scenario, and nearly all of global MRB would be converted into 16 EJ y^{-1} of energy by the end of the century under a climate policy scenario.

11/00611 Optimal power flow for large-scale power system with shunt FACTS using efficient parallel GA

Mahdad, B. *et al. International Journal of Electrical Power & Energy Systems*, 2010, 32, (5), 507–517.
The main disadvantage of GAs is the high CPU time execution and the qualities of the solution deteriorate with practical large-scale optimal power flow (OPF) problems. This paper presents an efficient parallel GA (EPGA) for the solution of large-scale OPF with consideration of practical generators constraints. The length of the original chromosome is reduced successively based on the decomposition level and adapted with the topology of the new partition. Partial decomposed active power demand added as a new variable and searched within the active power generation variables of the new decomposed chromosome. The strategy of the OPF problem is decomposed in two sub-problems, the first sub-problem related to active power planning to minimize the fuel cost function, and the second sub-problem designed to make corrections to the voltage deviation and reactive power violation based in an efficient reactive power planning of multi Static VAR Compensator (SVC). Numerical results on three test systems IEEE 30-Bus, IEEE 118-Bus and 15 generation units with prohibited zones are presented and compared with results of others competitive global approach. The results show that the proposed approach can converge to the optimum solution, and obtains the solution with high accuracy.

11/00612 Retrofitting of municipal coal fired heating plant with integrated biomass gasification gas turbine based cogeneration block

Kalina, J. *Energy Conversion and Management*, 2010, 51, (5), 1085–1092.
Biomass has a significant potential for reduction of both CO_2 emission and consumption of fossil fuels in energy production sector. On the other hand the successful implementation of biomass into regional energy systems is strongly influenced by many political, economic and technical factors. The best effects can be obtained if a proper choice of biomass plant technology has been made. The objective of this work is the analysis and discussion of technical and economic benefits of retrofitting an existing coal-fired municipal heating plant with integrated biomass gasification cogeneration block. The project leads to both local and global reduction of emission and fossil fuels consumption. An investment decision is however dependent on economic profitability, which is also examined in this work. Four design alternatives were proposed and modelled with using Cycle-Tempo simulation software. An annual mass and energy balance of the plant was calculated and economic analysis was performed. The results indicate a great energy and emission savings potential. An effective financial support, that results from local renewable energy promotion policy, can make an economic performance of the project attractive. The best technical solution for the retrofitting the analysed heating plant was the combined cycle integrated with gasification of biomass with steam.

11/00613 Robust control of doubly fed induction generator for stand-alone applications

Belfedal, C. *et al. Electric Power Systems Research*, 2010, 80, (2), 230–239.
The doubly fed induction generator (DFIG) is generally used in the production of the electric energy and more specifically in wind turbines. Currently, a problem of electrical machine control and especially for wind turbines is the change of internal parameters of the machine, which greatly deteriorates the control. In addition, for stand-alone applications, the load and wind speed change frequently. In this paper, a robust control strategy based on the H_∞ control theory is developed for the independent control of the stator voltage amplitude and frequency of a stand-alone DFIG. The DFIG is fed through the rotor windings by a voltage inverter controlled by space vector modulation. A capacitive and inductive filter is introduced to reduce harmonics on stator voltages and rotor currents. The robust control strategy rejects all the disturbances that may affect the system and that result from the variations of machine parameters, of the rotor speed and of the load. Experimental tests are carried out to verify the effectiveness of the robust control through a comparison with the classical PI regulator in the framework of the field oriented control strategy of the DFIG.

11/00614 Steady-state modelling of hybrid energy system for off grid electrification of cluster of villages

Gupta, A. *et al. Renewable Energy*, 2010, 35, (2), 520–535.
Electrification of villages from the main grid leads to large investments and losses, and this forms the basis of decentralized Hybrid energy system. In order to evaluate the techno-economic performance of hybrid energy system for remote rural area electrification, a mixed integer linear mathematical programming model (time-series) has been developed to determine the optimal operation, optimal configuration including the assessment of the economic penetration levels of photovoltaic array area, and cost optimization for a hybrid energy generation system consisting of small/microhydro-based power generation, biogas-based power generation, biomass (fuelwood) based power generation, photovoltaic array, a battery bank and a fossil fuel

generator. An optimum control algorithm written in the computer language C++, based on combined dispatch strategy, allowing easy handling of the models and data of hybrid energy system components is presented. A special feature of the proposed model is that a cost constant (cost/unit) for each of the proposed resource is introduced in the cost objective function in such a way that resources with lesser unit cost share the greater of the total energy demand in an attempt to optimize the objective function. To demonstrate the use of model and algorithm, a case study for a rural remote area is also presented.

11/00615 Trigeneration running with raw jatropha oil
Wang, Y. *et al. Fuel Processing Technology*, 2010, 91, (3), 348–353.
The performance and the efficiency of a trigeneration system fuelling with pure diesel and with raw jatropha oil are investigated using the ECLIPSE software. The study is based on a diesel engine generating set. The genset is used for electrical power generation only, acting as a single generation. The trigeneration system consists of the genset, a waste heat recovery system and an absorption refrigerator. The genset is used to generate electricity; the waste heat system is used to collect the waste heat from the cooling system and the exhaust from the engine, to supply heating/hot water; and the absorption refrigerator is used to supply cooling/refrigeration, which is driven by the waste heat from the engine instead of electricity. A comparison of the thermal efficiencies and the CO_2 emissions of trigeneration with single generation and cogeneration (combined heat and power – CHP) is carried out. The results from the study show that the thermal efficiency of trigeneration is higher than that of single generation; the CO_2 emissions of trigeneration are lower than that of single generation. The results also show the performance differences between the trigeneration and single generation; and the differences between trigeneration and cogeneration.

Economics, policy, supplies, forecasts

11/00616 A hybrid GA–PS–SQP method to solve power system valve-point economic dispatch problems
Alsumait, J. S. *et al. Applied Energy*, 2010, 87, (5), 1773–1781.
This study presents a new approach based on a hybrid algorithm consisting of Genetic Algorithm (GA), Pattern Search (PS) and Sequential Quadratic Programming (SQP) techniques to solve the well-known power system Economic dispatch problem (ED). GA is the main optimizer of the algorithm, whereas PS and SQP are used to fine tune the results of GA to increase confidence in the solution. For illustrative purposes, the algorithm has been applied to various test systems to assess its effectiveness. Furthermore, convergence characteristics and robustness of the proposed method have been explored through comparison with results reported in literature. The outcome is very encouraging and suggests that the hybrid GA–PS–SQP algorithm is very efficient in solving power system economic dispatch problem.

11/00617 Demand response in China
Wang, J. *et al. Energy*, 2010, 35, (4), 1592–1597.
The escalating demand for electricity in China has caused an electricity shortage in the past several years. This paper discusses the role of demand response (DR) as an integral component in alleviating the problem and coping with this shortfall. It reviews current experience with DR programs, analyses China's situation and makes suggestions for DR implementation. Although China's DR programs offer high potential to succeed, they require substantial efforts in resolving such key issues as the programs' funding mechanisms, pricing, and relationship with electricity industry reform.

11/00618 Design of the incentive mechanism in electricity auction market based on the signaling game theory
Liu, Z. *et al. Energy*, 2010, 35, (4), 1813–1819.
At present, designing a proper bidding mechanism to decrease the generators' market power is considered to be one of the key approaches to deepen the reform of the electricity market. Based on the signalling game theory, the paper analyses the main electricity bidding mechanisms in the electricity auction markets and considers the degree of information disturbance as an important factor for evaluating bidding mechanisms. Under the above studies, an incentive electricity bidding mechanism defined as the generator semi-randomized matching (GSM) mechanism is proposed. In order to verify the new bidding mechanism, this paper uses the swarm platform to develop a simulation model based on the multi-agents. In the simulation model, the generators and purchasers use the partly superior study strategy to adjust their price and their electricity quantity. Then, the paper examines a simulation experiment of the GSM bidding mechanism and compares it to a simulation of the high-low matching (HLM) bidding mechanism. According to the simulation results, several conclusions can be drawn when comparing the proposed GSM bidding mechanism to the equilibrium state of HLM: the clearing price decreases, the total transaction volume increases, the profits of electricity generators decreases, and the overall benefits of purchasers increases.

11/00619 Distribution planning with reliability options for distributed generation
Trebolle, D. *et al. Electric Power Systems Research*, 2010, 80, (2), 222–229.
The promotion of electricity generation from renewable energy sources (RES) and combined heat and power (CHP) has resulted in increasing penetration levels of distributed generation. However, large-scale connection of distributed generation involves profound changes in the operation and planning of electricity distribution networks. Distribution system operators (DSOs) play a key role since these agents have to provide flexibility to their networks in order to integrate distributed generation. Article 14.7 of EU Electricity Directive states that DSOs should consider distributed generation as an alternative to new network investments. This is a challenging task, particularly under the current regulatory framework where DSOs must be legally and functionally unbundled from other activities in the electricity sector. This paper proposes a market mechanism, referred to as reliability options for distributed generation (RODG), which provides DSOs with an alternative to the investment in new distribution facilities. The mechanism proposed allocates the firm capacity required to distributed generation embedded in the distribution network through a competitive auction. Additionally, RODG make distributed generation partly responsible for reliability and provide distributed generation with incentives for a more efficient operation taking into account the network conditions.

11/00620 District heating in case of power failure
Lauenburg, P. *et al. Applied Energy*, 2010, 87, (4), 1176–1186.
Power failures in combination with harsh weather conditions during recent years have led to an increased focus on safe energy supplies. Many vital functions are dependent on electricity but perhaps the most critical of all are heating systems. In Sweden, district heating (DH) is the most common type of heating for buildings in town centres. The present study shows that, by maintaining the DH production as well as the operation of the DH network, possibilities to supply connected buildings with space heat are surprisingly good. This is due to the fact that natural circulation will most often take place in radiator systems. In Sweden, and in many other countries, so-called indirect connection (heat supply across heat exchangers) of DH substations is applied. If a DH network operation can be maintained during a power failure, DH water will continue to pass the radiator system's heat exchanger (HEX), provided that the control valve does not close. The radiator circulation pump will stop, causing the radiator water to attain a relatively high temperature in the HEX, which promotes a natural circulation in the hydronic heating system, due to an increased water density differential at different temperatures. Several field tests and computer simulations have been performed and have displayed that almost all buildings can achieve a space heat supply corresponding to 40–80% of the amount prior to the interruption. A sufficient heat load in the DH network can be vital in certain cases: e.g. for 'island-operation' of an electric power plant to be performed during a power failure. Furthermore, for many combined heat and power stations, a requirement involves that the DH network continues to provide a heat sink when no other cooling is available. Based on the findings presented herein, a set of recommendations have been set up to provide advice to, among others, DH utilities and owners of customer buildings.

11/00621 Does electricity (and heat) network regulation have anything to learn from fixed line telecoms regulation?
Pollitt, M. *Energy Policy*, 2010, 38, (3), 1360–1371.
This study examines the deregulation of fixed line telecoms in the UK and the lessons that it seems to suggest. These lessons are then applied to the electricity networks in the context of a possible increase in distributed generation directly connected to local distribution networks. It is concluded that there is the possibility of more parallels over time and suggest several implications of this for the regulation of electricity and heat networks.

11/00622 Electricity market equilibrium model with resource constraint and transmission congestion
Gao, F. and Sheble, G. B. *Electric Power Systems Research*, 2010, 80, (1), 9–18.
An electricity market equilibrium model not only helps independent system operators and regulators analyse market performance and market power, but also provides market participants the ability to build optimal bidding strategies based on microeconomics analysis. Supply function equilibrium (SFE) is attractive compared to traditional models and much effort has been given to it. However, most past research focused on a single-period, single-market model and did not

address the fact that generating companies hold a portfolio of assets in both electricity and fuel markets. This paper first identifies a proper SFE model, which can be applied to a multiple-period situation. Then the paper develops the equilibrium condition using discrete time optimal control considering fuel resource constraints. Finally, the paper discusses the issues of multiple equilibria caused by transmission network and shows that a transmission constrained equilibrium may exist, however the shadow price may not be zero. Additionally, an advantage from the proposed model for merchant transmission planning is discussed.

11/00623 Energy efficiency analysis and impact evaluation of the application of thermoelectric power cycle to today's CHP systems

Chen, M. *et al. Applied Energy*, 2010, 87, (4), 1231–1238.

High efficiency thermoelectric generators (TEG) can recover waste heat from both industrial and private sectors. Thus, the development and deployment of TEG may represent one of the main drives for technological change and fuel substitution. This paper will present an analysis of system efficiency related to the integration of TEG into thermal energy systems, especially combined heat and power production (CHP). Representative implementations of installing TEG in CHP plants to utilize waste heat, wherein electricity can be generated *in situ* as a by-product, will be described to show advantageous configurations for combustion systems. The feasible deployment of TEG in various CHP plants will be examined in terms of heat source temperature range, influences on CHP power specification and thermal environment, as well as potential benefits. The overall conversion efficiency improvements and economic benefits, together with the environmental impact of this deployment, will then be estimated. By using the Danish thermal energy system as a paradigm, this paper will consider the TEG application to district heating systems and power plants through the EnergyPLAN model, which has been created to design suitable energy strategies for the integration of electricity production into the overall energy system.

11/00624 Evolution and current status of demand response (DR) in electricity markets: insights from PJM and NYISO

Walawalkar, R. *et al. Energy*, 2010, 35, (4), 1553–1560.

In electricity markets, traditional demand side management programs are slowly getting replaced with demand response (DR) programs. These programs have evolved since the early pilot programs launched in late 1990s. With the changes in market rules the opportunities have generally increased for DR for participating in emergency, economic and ancillary service programs. In recent times, various regulators have suggested that DR can also be used as a solution to meet supply – demand fluctuations in scenarios with significant penetration of variable renewable sources in grid. This paper provides an overview of the evolution of the DR programs in PJM and NYISO markets as well as analyses current opportunities. Although DR participation has grown, most of the current participation is in the reliability programs, which are designed to provide load curtailment during peak days. This suggests that there is a significant gap between perception of ability of DR to mitigate variability of renewables and reality of current participation. DR in future can be scaled to play a more dynamic role in electricity markets, but that would require changes both on technology as well as policy front. Advances in building technologies and energy storage combined with appropriate price signals can lead to enhanced DR participation.

11/00625 Ex post monitoring of market power in hydro dominated electricity markets

Sandsmark, M. and Tennbakk, B. *Energy Policy*, 2010, 38, (3), 1500–1509.

The paper presents a proposed market monitoring procedure that takes into account the special features of an electricity market dominated by hydropower. Specifically, a method is presented to assess water values and a set of indicators that can be used to screen the market for suspicious price formation. The suggested monitoring procedure was then used to evaluate actual price formation in the Nordic electricity market during the (hydrological) year 2002/2003 when precipitation failed and spot prices at the electricity exchange Nord Pool hit an all-time high.

11/00626 Fault detection, diagnosis and data recovery for a real building heating/cooling billing system

Chen, Y. and Lan, L. *Energy Conversion and Management*, 2010, 51, (5), 1015–1024.

A method of fault detection, diagnosis (FDD) and data recovery is proposed for building heating/cooling billing system in this paper. Principal component analysis (PCA) approach is used to extract the correlation of measured variables in heating/cooling billing system and reduce the dimension of measured data. The measured data of billing system under normal operating condition are used to build PCA model. Sensor faults of bias, drifting and complete failure are introduced to building heating/cooling billing system for detection and identification. Square prediction error (SPE) statistic is used to detect sensor faults in the system. Then, sensor validity index (SVI) was employed to identify faulty sensors. Finally, a reconstruction algorithm is presented to recover the correct data of faulty sensor in accordance with the correlations among system variables. A program for the FDD and data recovery method is developed and employed in the heating/cooling billing system of a real small-scale laboratory building to test its applicability and effectiveness. Validation results show that the proposed FDD and data recovery method is correct and effective for most faults in building heating/cooling billing system.

11/00627 Multi-market energy procurement for a large consumer using a risk-aversion procedure

Zare, K. *et al. Electric Power Systems Research*, 2010, 80, (1), 63–70.

This paper provides a technique to derive the bidding strategy in the day-ahead market of a large consumer that procures its electricity demand in both the day-ahead market and a subsequent adjustment market. Price uncertainty is modelled using concepts derived from information gap decision theory, which allows deriving robust decisions with respect to price volatility. Risk aversion is built implicitly within the proposed model. Correlations among prices in the day-ahead and the adjustment markets are properly modelled. The proposed technique is illustrated through a realistic case study.

11/00628 Potential and cost of electricity generation from human and animal waste in Spain

Gómez, A. *et al. Renewable Energy*, 2010, 35, (2), 498–506.

The energy contents of human and animal waste generated in Spain is estimated, as is the electricity that could be potentially generated from such waste. The waste considered is municipal solid waste, sewage sludge and livestock manure; several energy-recovery options are analysed for the first one, namely the collection of landfill gas, incineration and anaerobic digestion. To estimate the potential, geo-referenced statistical human and animal population data are used disaggregated to county level. This level of disaggregation allows the implementation of a cost model for the transformation of the waste into electricity, using a variety of technologies. The model considers the cost of transporting the waste to the transformation plant, and takes into account the economies of scale afforded by larger plants for the combined treatment of the waste in the county. The result is a generation–cost curve, which sorts by increasing costs the generation potential in the whole of the territory. The overall limits, in terms of primary energy and without considering alternative uses for the waste are between 725 and 4438 ktoe/y (depending on the energy-recovery method) for municipal solid waste; 142 ktoe/y for sewage sludge; and 1794 ktoe/y for livestock manure. The cost of the electricity generated depends greatly on the type of residue and the technology used for the transformation. Thus, the most economical option is the incineration of municipal solid waste, with an entry cost of around 4 c€/kWh. The generation entry-costs from livestock manure and sewage sludge are on the other hand in excess of 8 c€/kWh.

11/00629 Real and reactive power loss allocation in pool-based electricity markets

Alturki, Y. A. and Lo, K. L. *International Journal of Electrical Power & Energy Systems*, 2010, 32, (3), 262–270.

Although real power is the main traded commodity in electricity markets, reactive power plays crucial roles in power systems reliability and security. Market participants utilize the network differently to maximize their profits. It means that their effects on the system, such as losses, can also be different. The development of a fair and accurate loss allocation scheme for real and reactive power is significant to avoid cross subsidies and to have the correct charge for each participant. This paper introduces a new method to allocate real and reactive losses in pool-based markets. The basic idea assumes that network users have their own effects on the system as well as their interactive effects which are based on their contributions to currents flows. The proposed method determines these contributions and adjusts them, due to system nonlinearity, according to current adjustment factors. Unlike other approaches, the proposed method can easily and effectively allocate real and reactive losses simultaneously without any additional calculation except the substitution of line reactance instead of resistance. The proposed method is illustrated on a simple system and tested on the standard IEEE-14-bus and IEEE-30-bus systems. Results have shown validity and consistency of the proposed method.

11/00630 Reconfiguration of distribution networks to minimize loss and disruption costs using genetic algorithms

Cebrian, J. C. and Kagan, N. *Electric Power Systems Research*, 2010, 80, (1), 53–62.

In this paper a computational implementation of an evolutionary algorithm is shown in order to tackle the problem of reconfiguring radial distribution systems. The developed module considers power quality indices such as long duration interruptions and customer

process disruptions due to voltage sags, by using the Monte Carlo simulation method. Power quality costs are modelled into the mathematical problem formulation, which are added to the cost of network losses. As for the evolutionary algorithm codification proposed, a decimal representation is used. The evolutionary algorithm operators, namely selection, recombination and mutation, which are considered for the reconfiguration algorithm, are analysed here. A number of selection procedures are analysed, namely tournament, elitism and a mixed technique using both elitism and tournament. The recombination operator was developed by considering a chromosome structure representation that maps the network branches and system radiality, and another structure that takes into account the network topology and feasibility of network operation to exchange genetic material. The topologies regarding the initial population are randomly produced so as radial configurations are produced through the Prim and Kruskal algorithms that rapidly build minimum spanning trees.

11/00631 Risks, revenues and investment in electricity generation: why policy needs to look beyond costs
Gross, R. *et al. Energy Economics*, 2010, 32, (4), 796–804.
Energy policy goals frequently depend upon investment in particular technologies, or categories of technology. While the British government has often espoused the virtues of technological neutrality, UK policies now seek to promote nuclear power, coal with CO_2 capture and storage, and renewable energy. Policy decisions are often informed by estimates of cost per unit of output (for example, £/MWh), also known as levelized costs. Estimates of these costs for different technologies are often used to provide a 'ballpark' guide to the levels of financial support needed (if any) to encourage uptake, or direct investment away from the technologies the market might otherwise have chosen. Levelized cost estimates can also help to indicate the cost of meeting public policy objectives, and whether there is a rationale for intervention (for example, based on net welfare gains). In the UK electricity sector, investment is undertaken by private companies, not governments. Investment is driven by expected returns, in the light of a range of risks related to both costs and revenues. Revenue risks are not captured in estimates of cost or cost-related risks. An important category of revenue risk is associated with electricity price fluctuations. Exposure to price risks differs by technology. Low electricity prices represent a revenue risk to technologies that cannot influence electricity prices. By contrast, 'price makers' that set marginal prices are, to an extent, able to pass fuel price increases through to consumers. They have an inherent 'hedge' against fuel and electricity price fluctuations. Based on recent research by the UK Energy Research Centre, this paper considers the implications of such price risks for policy design. The authors contrast the range of levelized costs estimated for different generating options with the spread of returns each is exposed to when electricity price fluctuations are factored in. Drawing on recent policy experiences in the renewable energy arena, in the UK and elsewhere, the authors provide an assessment of investment risk in policy effectiveness and consider how policy design can increase or ameliorate price risk. They discuss the circumstances under which policy goals might be best served by 'socializing' price risk, through fixed price policies. The importance of increased and explicit attention to revenue risk in policymaking is discussed, along with the means by which this might be achieved.

11/00632 Sensitivity of system operating considerations in generating capacity adequacy evaluation
Billinton, R. and Huang, D. *International Journal of Electrical Power & Energy Systems*, 2010, 32, (3), 178–186.
Generating capacity adequacy assessment is an important activity in power system planning and development. This procedure usually involves the development of suitable generating capacity models and the convolution of these models with appropriate system load or demand models. Generating capacity models are usually assumed to be independent of the load models and use fixed generating unit capacity and reliability parameters determined from design and operating statistics. The basic model for a base load generating unit is a two-state model representation in which the unit is either in service or unavailable for service. This is a valid representation for a base load unit but does not adequately represent intermittent operating units used to meet peaking load conditions. The two-state model for a base load unit has been extended to a four state representation, which is widely used in practice. In this case, the conventional generating unit forced outage rate (FOR) is replaced by the utilization forced outage probability (UFOP), which is the probability of the generating unit being unavailable given that the system needs it. The calculated UFOP is not a fixed value but varies depending upon the operating role played by the unit. This paper illustrates the utilization of a sequential Monte Carlo simulation technique for generating system adequacy evaluation and examines the response of the reliability parameters associated with intermittent operating units to changes in the generating unit loading order, the required reserve, the system peak load and other system conditions.

11/00633 Study on a multifunctional energy system producing coking heat, methanol and electricity
Sun, S. *et al. Fuel*, 2010, 89, (7), 1353–1360.
A multifunctional energy system (MES) capable of consuming coke oven gas (COG) and coal, and simultaneously producing coking heat, methanol and electricity, was subject to an exergy analyses based on energy utilization diagrams. In this system a coal-fired coke oven is adopted to produce coke and COG, where non-coking coal is burned to supply thermal energy to the coking process. The COG and coal gas gasified from coal in a gasifier, were mixed to produce syngas for methanol synthesis. Since COG rich in hydrogen and coal gas rich in CO, the mixture of COG and coal gas can easily adjust the mole ratio of CO to H_2 of syngas instead of the conversional reforming and shift processes. The active component of syngas is firstly converted into methanol and then the rest is introduced to a gas turbine for power generation. As a result, the overall efficiency of the MES system is about 62.3%, and its energy savings ratio is about 15% comparing with individual systems. The paper provides a new approach to use coal more efficiently and cleanly.

11/00634 The impact of covered overhead conductors on distribution reliability and safety
Li, M.-B. *et al. International Journal of Electrical Power & Energy Systems*, 2010, 32, (3), 281–289.
A modern electric distribution system must provide a certain level of reliability for customers. In addition, decreasing the harm to life due to accidents associated with distribution systems should receive considerable attention. For overhead distribution systems, the reliability of covered overhead lines could potentially be improved using various alternative technologies. The statistical two-sample t significance test presented in this paper can be used to determine the cause-and-effect relationships that exist between the covered rates and the reliability indices including public safety. Moreover, because outage events occur at unpredictable times and for different reasons, the Monte Carlo simulation approach (MCSA) is a useful method that can use a computer to rapidly generate a large number of trials that simulate outage events. The MCSA is applied in accordance with the strong law of large numbers to obtain reliability and safety indices for a distribution system. A practical test system is employed to analyse and simulate the reliability index and safety index results.

11/00635 Transmission surplus capacity based power transmission expansion planning
Qu, G. *et al. Electric Power Systems Research*, 2010, 80, (1), 19–27.
A power transmission expansion planning model with consideration of transmission surplus capacity and network load factor is presented. With a traditional planning model, some transmission lines will operate on high load factors due to ignorance of the load levels of transmission lines. This may lead to network congestion or degrade the dispatch flexibility of the future network. The traditional planning model has put more emphasis on investment cost rather than on other aspects such as operation environment, transmission benefit, etc. The transmission expansion planning model in this paper aims to maximize network transmission surplus capacity and optimize network load factor distribution with least investment. The chaos optimal algorithm is introduced to solve this non-linear integer planning optimization problem because of its advantage of stochastic and ergodic searching characteristics. The effectiveness of proposed model and methodology is tested with two typical systems.

07 STEAM RAISING

Boiler operation/design

11/00636 A case study on detection and sizing of defects in steam generator tubes using eddy current testing
Hur, D. H. *et al. Nuclear Engineering and Design*, 2010, 240, (1), 204–208.
Eddy current testing (ECT) method is widely used to detect various types of defects occurring in nuclear steam generator tubes. Therefore, the reliability of its detection and sizing accuracy for defects should be validated. For this purpose, two tubes with defect signals were pulled from an operating steam generator and destructively examined. The defect type was a circumferential crack for one tube and an intergranular attack (IGA) for the other tube. The plus point coil probe showed a better capability to detect and size both a

circumferential crack and a volumetric IGA than pancake and bobbin coil probe. The destructive results are correlated with the ECT results obtained during the in-service inspection.

11/00637 Design assessment of a 150 kWt CFBC test unit

Batu, A. *et al. Experimental Thermal and Fluid Science*, 2010, 34, (3), 275–281.

For the clean and efficient generation of energy from coal, the most suitable technology known to date is fluidized bed combustion technology. Applications of circulating fluidized bed (CFB) combustion (CFBC) technology have been steadily increasing in both capacity and number over the past decade. Designs of these units have been based on the combustion tests carried out in pilot-scale facilities to determine the combustion and desulfurization characteristics of coal and limestone reserves in CFB conditions. Similarly, utilization of Turkish lignites in CFB boilers necessitates adaptation of CFB combustion technology to these resources. However, the design of these test units are not based on firing coals with high ash, volatile matter and sulfur contents like Turkish lignites. For this purpose, a 150 kWt CFB combustor test unit was designed and constructed in Chemical Engineering Department of Middle East Technical University, based on the extensive experience acquired at the existing 0.3 MWt bubbling atmospheric fluidized bed combustor (AFBC) test rig. Following the commissioning tests, a combustion test was carried out to investigate the combustion characteristics of Çan lignite in CFB conditions and for the assessment of the design of the test unit. Comparison of the design outputs with experimental results reveals that most of the predictions and assumptions have acceptable agreement with the operating conditions. In conclusion, the performance of 150 kWt CFBC test unit is found to be satisfactory to be used for long-term research studies on combustion and desulfurization characteristics of indigenous lignite reserves in CFB combustors.

11/00638 Evaluation of ECT reliability for axial ODSCC in steam generator tubes

Lee, J. B. *et al. International Journal of Pressure Vessels and Piping*, 2010, 87, (1), 46–51.

The integrity of steam generator tubes is usually evaluated based on eddy current test (ECT) results. Because detection capacity of the ECT is not perfect, all of the physical flaws, which actually exist in steam generator tubes, cannot be detected by ECT inspection. Therefore it is very important to analyse ECT reliability in the integrity assessment of steam generators. The reliability of an ECT inspection system is divided into reliability of inspection technique and reliability of quality of analyst. And the reliability of ECT results is also divided into reliability of size and reliability of detection. The reliability of ECT sizing is often characterized as a linear regression model relating true flaw size data to measured flaw size data. The reliability of detection is characterized in terms of probability of detection (POD), which is expressed as a function of flaw size. In this paper the reliability of an ECT inspection system is analysed quantitatively. POD of the ECT inspection system for axial outside diameter stress corrosion cracks (ODSCC) in steam generator tubes is evaluated. Using a log-logistic regression model, POD is evaluated from hit (detection) and miss (no detection) binary data obtained from destructive and non-destructive inspections of cracked tubes. Crack length and crack depth are considered as variables in multivariate log-logistic regression and their effects on detection capacity are assessed using two-dimensional POD (2-D POD) surface. The reliability of detection is also analysed using POD for inspection technique (POD_T) and POD for analyst (POD_A).

11/00639 Improved load control for a steam cycle combined heat and power plant

Jonshagen, K. and Genrup, M. *Energy*, 2010, 35, (4), 1694–1700.

The problem of optimum load control of steam power plants has been dealt within many technical papers during the last decades. Deregulation of the power markets and close to the (bio-) fuel source thinking has lead to a trend of small scale combined heat and power plants. These plants are usually operated according to the heat demand and therefore they spend a significant time on partial load. The load control of such plants is in general done by partial arc control. This work applies a hybrid control strategy, which is a combination of partial arc control and sliding pressure control. The method achieves further improvement in performance at partial load. Hybrid control itself is not novel and has earlier been used on traditional coal-fired condensing plants. This has, to the author's knowledge, not earlier been applied on combined heat and power plants. The results show that there is a potential for improved electricity production at a significant part of the load range.

11/00640 Influence of outer secondary-air vane angle on combustion characteristics and NO_x emissions of a down-fired pulverized-coal 300 MWe utility boiler

Fan, S. *et al. Fuel*, 2010, 89, (7), 1525–1533.

Industrial experiments were performed on a down-fired pulverized-coal 300 MWe utility boiler with swirl burners. Gas temperature, concentrations of gas components (O_2, CO, CO_2 and NO_x) in the burning region and carbon content in the fly ash were measured with outer secondary-air vane angles of 25°, 32.5° and 50°. Results indicate that with increasing vane angle, NO_x emission and boiler efficiency decrease. Overall evaluation boiler efficiency and NO_x emission, the vane angle of 32.5° is optimum. Using an IFA300 constant-temperature anemometer system, cold air experiments on a quarter-scaled burner model were also carried out to investigate the influence of various outer secondary-air vane angles on the flow characteristics in the burner nozzle region. No central recirculation zone appeared for vane angles of 25° and 32.5°. Most of the pulverized-coal was ignited in the external recirculation zone. For vane angles of 45° and 55°, a central recirculation zone could be observed, and air flow rigidity and axial velocities decreased rapidly.

11/00641 Measurement of gas species, temperatures, char burnout, and wall heat fluxes in a 200-MW_e lignite-fired boiler at different loads

Li, Z. *et al. Applied Energy*, 2010, 87, (4), 1217–1230.

The authors measured various operational parameters of a 200-MW_e, wall-fired, lignite utility boiler under different loads. The parameters measured were gas temperature, gas species concentration, char burnout, component release rates (C, H and N), furnace temperature, heat flux, and boiler efficiency. Cold air experiments of a single burner were conducted in the laboratory. A double swirl flow pulverized-coal burner has two ring recirculation zones that start in the secondary air region of the burner. With increasing secondary air flow, the air flow axial velocity increases, the maximum values for the radial velocity, tangential velocity, and turbulence intensity all increase, and there are slight increases in the air flow swirl intensity and the recirculation zone size. With increasing load gas, the temperature and CO concentration in the central region of burner decrease, while O_2 concentration, NO_x concentration, char burnout, and component release rates of C, H, and N increase. Pulverized-coal ignites further into the burner, in the secondary air region. Gas temperature, O_2 concentration, NO_x concentration, char burnout and component release rates of C, H, and N all increase. Furthermore, CO concentration varies slightly and pulverized-coal ignites closer. In the side wall region, gas temperature, O_2 concentration, and NO_x concentration all increase, but CO concentration varies only slightly. In the bottom row burner region the furnace temperature and heat flux increase appreciably, but the increase became more obvious in the middle and top row burner regions and in the burnout region. Compared with a 120-MW_e load, the mean NO_x emission at the air preheater exits for 190-MW_e load increases from 589.5 mg/m^3 (O_2 = 6%) to 794.6 mg/m^3 (O_2 = 6%), and the boiler efficiency increases from 90.73% to 92.45%.

11/00642 Optimization of boiler cold-end and integration with the steam cycle in supercritical units

Espatolero, S. *et al. Applied Energy*, 2010, 87, (5), 1651–1660.

In order to gain an extra increment of efficiency to compensate for capital costs, one of the main issues in the design of advanced supercritical power plants is the reduction of boiler exit gas temperature below typical values of conventional, subcritical units. Currently, the use of heat exchange surfaces made of plastic has become feasible, thereby avoiding corrosion and fouling problems derived from cold-end acid condensate. In this manner, flue gas temperature can be reduced down to typically 90 °C, which obviously leads to an increase of boiler efficiency. Besides, there is an additional energy available for heating the main condensate flow of the power cycle. If the modification of air–gas rotary heaters is also considered, a manifold of possibilities opens up for plant optimization and integration of components. The objective of this paper is to analyse this class of schemes for increasing power output and net efficiency of a reference supercritical plant. A complete simulation of the steam cycle is assembled using Aspen Plus and different plant configurations are examined under reduced exit gas temperatures. Several uses of flue gas energy are considered, taking into account limits of temperature and realistic efficiencies of heat exchangers. Mass flow rates, point of extraction of condensate, pressures and temperatures are selected heuristically to optimize performance. Finally, required exchange areas are estimated, and a cost analysis is carried out in order to economically assess the new configurations and estimate the additional profit for the plant.

11/00643 Steam versus coking coal and the acid rain program

Lange, I. *Energy Policy*, 2010, 38, (3), 1251–1254.

The Clean Air Act of 1990 initiated a tradable permit program for emissions of sulfur dioxide from coal-fired power plants. One effect of this policy was a large increase in the consumption of low-sulfur bituminous coal by coal-fired power plants. However, low-sulfur bituminous coal is also the ideal coking coal for steel production.

The analysis presented here will attempt to determine how the market responded to the increased consumption of low-sulfur bituminous coal by the electricity generation sector. Was there a decrease in the quality and/or quantity of coking coal consumption or did extraction increase? Most evidence suggests that the market for coking coal was unaffected, even as the extraction and consumption of low-sulfur bituminous coal for electricity generation increased substantially.

08 COMBUSTION

Burners, combustion systems

11/00644 Adiabatic laminar burning velocities of $CH_4 + H_2 +$ air flames at low pressures

Konnov, A. A. *et al. Fuel*, 2010, 89, (7), 1392–1396.

Experimental measurements of the adiabatic burning velocity in methane + hydrogen + air flames using the Heat Flux method are presented. The hydrogen content in the fuel was varied from 0 to 20%. Non-stretched flames were stabilized on a perforated plate burner from 20 to 100 kPa. The equivalence ratio was varied from 0.8 to 1.4. Adiabatic burning velocities of $CH_4 + H_2 +$ air mixtures were found in good agreement with the literature results at atmospheric pressure. Also low-pressure measurements in $CH_4 +$ air flames performed earlier were accurately reproduced. The effects of enrichment by hydrogen on the laminar burning velocity at low pressures have been studied for the first time. Calculated burning velocities using the Konnov mechanism are in satisfactory agreement with the experiments over the entire range of conditions. Pressure dependences of the burning velocities for the three fuels studied could be approximated by an empirical exponential correlation.

11/00645 Capture of carbon dioxide from flue or fuel gas mixtures by clathrate crystallization in a silica gel column

Adeyemo, A. *et al. International Journal of Greenhouse Gas Control*, 2010, 4, (3), 478–485.

A column of silica gel was employed to contact water with flue gas (CO_2/N_2) mixture to assess if CO_2 can be separated by hydrate crystallization. Three different silica gels were used. One with a pore size of 30 nm (particle size 40–75 μm) and two with a pore size of 100 nm and particle sizes of 40–75 and 75–200 μm respectively. The observed trends indicate that larger pores and particle size increase the gas consumption, CO_2 recovery, separation factor and water conversion to hydrate. Thus, the gel (gel #3) with the larger particle size and larger pore size was chosen to carry out experiments with concentrated CO_2 mixtures and for experiments in the presence of tetrahydrofuran (THF), which itself is a hydrate forming substance. Addition of THF reduces the operating pressure in the crystallizer but it also reduces the gas uptake. Gel #3 was also used in experiments with a fuel gas (CO_2/H_2) mixture in order to recover CO_2 and H_2. It was found that the gel column performs as well as a stirred reactor in separating the gas components from both flue gas and fuel gas mixtures. However, the crystallization rate and hydrate yield are considerably enhanced in the former. Finally the need for stirring is eliminated with the gel column which is enormously beneficial economically.

11/00646 Co-pyrolysis of lignite and sugar beet pulp

Yilgin, M. *et al. Energy Conversion and Management*, 2010, 51, (5), 1060–1064.

Today, worldwide studies have been undertaken on the biomass usage and co-conversion of biomass and coal to seek out alternative fuels for supplying energy in an environmental friendly way. The objective of this work is to study co-pyrolysis of lignite and sugar beet pulp in 50/50 (wt/wt) ratio of blend pellets, to elucidate their thermal behaviour under pyrolysis conditions and to assess major decomposition products in terms of their yields. A special chamber, which has enabled very fast heating rates, was used in the pyrolysis experiments carried at 600 °C. The results were interpreted in the light of liquid, solid and gaseous yields, resulting from thermal decomposition, and kinetics of thermogravimetric analysis. Proximate volatile matter and ash contents of the blends were different compared to those found by using individual values. Sugar beet pulp decomposed faster within a relatively narrow temperature range than lignite and underwent a significant shrinkage during pyrolysis. It was found that the chars left behind after the flash pyrolysis of these pellets at 600 °C have substantial amounts of volatile matter that would evolve upon further heating.

11/00647 Combustion visualization and experimental study on spark induced compression ignition (SICI) in gasoline HCCI engines

Wang, Z. *et al. Energy Conversion and Management*, 2010, 51, (5), 908–917.

Spark induced compression ignition (SICI) is a relatively new combustion control technology and a promising combustion mode in gasoline engines with high efficiency. SICI can be divided into two categories, SACI and SI–CI. This paper investigated the SICI combustion process using combustion visualization and engine experiment respectively. Ignition process of SICI was captured by high speed photography in an optical engine with different compression ratios. The results show that SICI is a combustion mode combined with partly flame propagation and main auto-ignition. The spark ignites the local mixture near spark electrodes and the flame propagation occurs before the homogeneous mixture is auto-ignited. The heat release from central burned zone due to the flame propagation increases the in-cylinder pressure and temperature, resulting in the unburned mixture auto-ignition. The SICI combustion process can be divided into three stages of the spark induced stage, the flame propagation stage and the compression ignition stage. The SICI combustion mode is different from the spark ignition (SI) knocking in terms of the combustion and emission characteristics. Furthermore, three typical combustion modes including HCCI, SICI, SI, were compared on a gasoline direct injection engine with higher compression ratio and switchable cam-profiles. The results show that SICI has an obvious combustion characteristic with two-stage heat release and lower pressure rise rate. The SICI combustion mode can be controlled by spark timings and EGR rates and utilized as an effective method for high load extension on the gasoline HCCI engine. The maximum IMEP of 0.82 MPa can be achieved with relatively low NO_x emission and high thermal efficiency. The SICI combustion mode can be applied in medium–high load region for high efficiency gasoline engines.

11/00648 Demonstration of a control system for combustion of lean hydrocarbon emissions in a reverse flow reactor

Marín, P. *et al. Chemical Engineering Science*, 2010, 65, (1), 54–59.

In this work, the performance of a simple logic-based controller for a reverse flow reactor (RFR) has been tested experimentally. The controller is a hybrid system using the inside reactor temperature as the controlled variable, and the switch of the flow direction as the manipulated variable. Three different control logic rules (depending on the point selected to measure the inside reactor temperature) have been compared for the catalytic combustion of methane in a bench-scale RFR unit. A procedure for tuning the controllers was established. The controller that measures the temperature in the middle of the reactor showed the best performance, as it provided complete methane conversion with high capacity to overcome both low and high feed concentration disturbances.

11/00649 Effect of flow field for colorless distributed combustion (CDC) for gas turbine combustion

Arghode, V. K. and Gupta, A. K. *Applied Energy*, 2010, 87, (5), 1631–1640.

Colourless distributed combustion (CDC) investigated here is focused on gas turbine combustion applications due to its significant benefits for, much reduced NO_x emissions and noise reduction, and significantly improved pattern factor. CDC is characterized by distributed reaction zone of combustion which leads to uniform thermal field and avoidance of hot spot regions to provide significant improvement in pattern factor, lower sound levels and reduced NO_x emission. Mixing between the combustion air and product gases to form hot and diluted oxidant prior to its mixing with the fuel is critical so that one must determine the most suitable mixing conditions to minimize the ignition delay. Spontaneous ignition of the fuel occurs to provide distributed reaction combustion conditions. The above requirements can be met with different configuration of fuel and air injections with carefully characterized flow field distribution within the combustion zone. This study examines four different sample configurations to achieve colourless distributed combustion conditions that reveal no visible colour of the flame. They include a baseline diffusion flame configuration and three other configurations that provide conditions close to distributed combustion conditions. For all four modes same fuel and air injection diameters are used to examine the effect of flow field configuration on combustion characteristics. The results are compared from the four different configurations on flow field and fuel/air mixing using numerical simulations and with experiments using global flame signatures, exhaust emissions, acoustic signatures, and thermal field. Both numerical simulations and experiments are performed at a constant heat load of 25 kW, using methane as the fuel at atmospheric pressure using normal temperature air and fuel. Lower NO_x and CO emissions, better thermal field uniformity, and lower acoustic levels have been observed when the flame approached CDC mode as compared to the baseline case of a diffusion flame. The

reaction zone is observed to be uniformly distributed over the entire combustor volume when the visible flame signatures approached CDC mode.

11/00650 Effect of particle size on pyrolysis of single-component municipal solid waste in fixed bed reactor

Luo, S. *et al. International Journal of Hydrogen Energy*, 2010, 35, (1), 93–97.

According to the differences in components, three representative components (plastic, kitchen garbage and wood) in municipal solid waste (MSW) were pyrolysed in a fixed bed reactor to evaluate the influence of particle size on pyrolysis performance of single-component municipal solid waste (MSW). The bed temperature was set at 800°C and each sample was separated into three different size fractions (0–5 mm, 5–10 mm and 10–20 mm). The results show for all the samples particle size has an effect on pyrolysis product yields and composition: smaller particle size results in higher gas yield with less tar and char; the decrease of particle size can increase H_2 and CO contents of gas, as well as the ash and carbon element contents in the char. And the influence is the much more significant for sample with higher fixed carbon and ash contents, such as kitchen garbage, and less for sample with higher volatile content, plastic in the test.

11/00651 Effects of secondary combustion on efficiencies and emission reduction in the diesel engine exhaust heat recovery system

Lee, D. H. *et al. Applied Energy*, 2010, 87, (5), 1716–1721.

An experimental study on the effects of secondary combustion on efficiencies and emission reduction in the diesel engine exhaust heat recovery system has been undertaken. The co-generation concept is utilized in that the electric power is produced by the generator connected to the diesel engine, and heat is recovered from both combustion exhaust gases and the engine by the fin-and-tube and shell-and-tube heat exchangers, respectively. A specially designed secondary combustor is installed at the engine outlet in order to reburn the unburned fuel from the diesel engine, thereby improving the system's efficiency as well as reducing air pollution caused by exhaust gases. The main components of the secondary combustor are coiled Nichrome wires heated by the electric current and diesel oxidation catalyst (DOC) housed inside a well-insulated stainless steel shell. The performance tests were conducted at four water flow rates of 5, 10, 15 and 20 L/min and five electric power outputs of 3, 5, 7, 9 and 11 kW. The results show that at a water flow of 20 L/min and a power generation of 9 kW, the total efficiency (thermal efficiency plus electric power generation efficiency) of this system reaches a maximum 94.4% which is approximately 15–20% higher than that of the typical diesel engine exhaust heat recovery system. Besides, the use of the secondary combustor and heat exchangers results in 80%, 35% and 90% reduction of carbon monoxide (CO), nitrogen oxide (NO_x) and particulate matter (PM), respectively.

11/00652 Experimental investigation of thermoacoustic coupling using blended hydrogen–methane fuels in a low swirl burner

Yilmaz, I. *et al. International Journal of Hydrogen Energy*, 2010, 35, (1), 329–336.

In this study, experimental testing and analysis were performed to examine the combustion instability characteristics of hydrogen–methane blended fuels for a low-swirl lean premixed burner. The aim of this study is to determine the effect of hydrogen addition on combustion instability, and this is assessed by examining the flame response to a range of constant amplitude, single frequency chamber acoustic modes. Three different blends of hydrogen and methane (93% CH_4–7% H_2, 80% CH_4–20% H_2 and 70% CH_4–30% H_2 by volume) were employed as fuel at an equivalence ratio of 0.5, and with four different acoustic excitation frequencies (85, 125, 222 and 399 Hz). Planar laser induced fluorescence of the hydroxyl radical (OH-PLIF) was employed to measure the OH concentration at different phases of acoustic excitation and a Rayleigh index was then calculated to determine the degree of thermoacoustic coupling. It was found, as has been previously reported, that the combustion characteristics are very sensitive to the fraction of hydrogen in the fuel mixture. The flame shows significant increases in flame base coupling and flame compaction with increasing hydrogen concentration for all conditions. While this effect enhances the flame response at non-resonant frequencies, it induces only minimal compaction and appears to decreases the coupling intensity at the resonant frequency.

11/00653 Experimental investigation on mixed refrigerant Joule–Thomson cryocooler with flammable and non-flammable refrigerant mixtures

Walimbe, N. S. *et al. Cryogenics*, 2010, 50, (10), 653–659.

Mixed refrigerant Joule–Thomson (MR J–T) cryocoolers have a wide application area over a temperature range from 80 to 200 K. The significant advantages of the system are the simplicity of its design and working reliability with high-level performance. This paper discusses the experimental results of MR J–T cooler with different flammable and non-flammable mixture compositions. The work highlights the use of pressure–enthalpy and temperature–enthalpy diagrams for these mixtures to support the experimental results. A record lowest temperature of 65 K and a cooling capacity of 6 W at 80 K are obtained for a single-stage MR J–T system starting at 300 K. Further, using a mixture of minimum flammable refrigerants, temperatures below 100 K is achieved.

11/00654 Experimental study of lean flammability limits of methane/hydrogen/air mixtures in tubes of different diameters

Shoshin, Y. L. and de Goey, L. P. H. *Experimental Thermal and Fluid Science*, 2010, 34, (3), 373–380.

Lean limit flames in methane/hydrogen/air mixtures propagating in tubes of internal diameters (ID) of 6.0, 8.9, 12.3, 18.4, 25.2, 35.0, and 50.2 mm have been studied experimentally. The flames propagated upward from the open bottom end of the tube to the closed upper end. The content of hydrogen in the fuel gas has been varied in the range 0–40 mol%. Lean flammability limits have been determined; flame shapes recorded and the visible speed of flame propagation measured. Most of the observed limit flames in tubes with diameters in the range of 8.9–18.4 mm had enclosed shape, and could be characterized as distorted or spherical flame balls. The tendency was observed for mixtures with higher hydrogen content to form smaller size, more uniform flame balls in a wider range of tube diameters. At hydrogen content of 20% or more in the fuel gas, limit flames in largest diameters (35.0 and 50.2 mm ID) tubes had small, compared to the tube diameter, size and were 'lens'-shaped. 'Regular' open-front lean limit flames were observed only for the smallest diameters (6.0 and 8.9 mm) and largest diameters (35.0 and 50.2 mm ID), and only for methane/air and (90% CH_4 + 10% H_2)/air mixtures, except for 6 mm ID tube in which all limit flames had open front. In all experiments, except for the lean limit flames in methane/air and (90% CH_4 + 10% H_2)/air mixtures in the 8.9 mm ID tube, and all limit flames in 6.0 mm ID tube, visible flame speeds very weakly depended on the hydrogen content in the fuel gas and were close to or below the theoretical estimate of the speed of a rising hot bubble. This observation suggests that the buoyancy is the major factor which determines the visible flame speed for studied limit flames, except that last mentioned. A decrease of the lean flammability limit value with decreasing the tube diameter was observed for methane/air and (90% CH_4 + 10% H_2)/air mixtures for tubes having internal diameters in the range of 18.4–50.2 mm. This effect has been attributed to the stronger combined effect of the preferential diffusion and flame stretch in narrower tubes for flames which resemble rising bubble.

11/00655 Flue gas desulfurization under simulated oxyfiring fluidized bed combustion conditions: the influence of limestone attrition and fragmentation

Scala, F. and Salatino, P. *Chemical Engineering Science*, 2010, 65, (1), 556–561.

Flue gas desulfurization by means of limestone injection under simulated fluidized bed oxyfiring conditions was investigated, with a particular focus on particle attrition and fragmentation phenomena. An experimental protocol was applied, based on the use of complementary techniques that had been previously developed for the characterization of attrition of sorbents in air-blown atmospheric fluidized bed combustors. The extent and pattern of limestone attrition by surface wear in the dense phase of a fluidized bed were assessed in bench-scale fluidized bed experiments under simulated oxyfiring conditions. Sorbent samples generated during the oxyfiring tests were further characterized from the standpoint of fragmentation on high velocity impact by means of a particle impactor. The experimental results were compared with those previously obtained with the same limestone under air-blown atmospheric fluidized bed combustion conditions. The profound differences in the attrition and fragmentation extents and patterns associated with oxyfiring as compared to air-blown atmospheric combustion and the role played by the different attrition/fragmentation paths were highlighted. In particular, it was noted that attrition could effectively enhance particle sulfation under oxyfiring conditions by continuously disclosing unconverted calcium to the sulfur-bearing atmosphere.

11/00656 Influence of flow field scaling on flashback of swirl flames

Blesinger, G. *et al. Experimental Thermal and Fluid Science*, 2010, 34, (3), 290–298.

In this paper, the effect of geometrical scaling on the onset of flashback into a cylindrical premixing zone of a swirl flame is investigated. Two types of flashback are considered. In the first type of flashback the

flame propagates upstream inside an already present axial recirculation zone. This flashback is caused by turbulent burning along the vortex axis (TBVA[1]) and is controlled by flame extinction inside the recirculation zone. The second type of flashback is caused by combustion induced vortex breakdown (CIVB[2]). This type of flashback is characterized by the aerodynamic influence of the combustion heat release that leads to propagation of the axial recirculation zone and the flame in upstream direction. To study the effects of geometrical scaling on the flow fields and the two types of flashback, the operation of two geometrically scaled burners are compared at equal Reynolds number. By this method it is possible to observe the flashback phenomena in similar swirl flow fields but with different turbulent scales affecting the combustion process. To check flow field similarity and to identify the flashback type, the non-reacting and reacting flow fields have been examined by planar particle imaging velocimetry and simultaneous recording of the flame luminescence. It is shown that geometrical scaling of the burner shifts the equivalence ratio at which flashback occurs and that this shift is different for the two types of flashback. Consistency and inconsistency with known scaling and stability criterions is discussed. Analysing the fluid dynamics and turbulent combustion gives a first explanation of why CIVB and TBVA are affected differently by geometrical scaling at constant Reynolds number which is in good agreement with the experimental observations.

11/00657 Influence of ZSM-5 zeolite on the pyrolytic intermediates from the co-pyrolysis of pubescens and LDPE

Liu, W. *et al. Energy Conversion and Management*, 2010, 51, (5), 1025–1032.

The catalytic reforming of the pyrolytic intermediates from the co-pyrolysis of pubescens and LDPE over the parent and desilicated zeolite ZSM-5 (DeZSM-5) was investigated. The results showed that the parent HZSM-5 exhibited high aromatization activity in the co-pyrolysis, whereas DeZSM-5 exhibited high alkanization activity. On the other hand, the total relative content of phenolic compounds in aqua obtained by co-pyrolysis catalysed by both parent HZSM-5 and DeZSM-5 was rather high (60–65%) compared to the thermal co-pyrolysis (26.94%). From the analysis of NH_3–TPD for ZSM-5, it might be proposed that the aromatization was favoured mainly by strong acid sites and the alkanization was favoured chiefly by weak acid sites in catalyst ZSM-5. In addition, the formation of phenolic compounds was mainly related to the interactions between the intermediates from the co-pyrolysis over ZSM-5.

11/00658 Integrated coal pyrolysis with CO_2 reforming of methane over Ni/MgO catalyst for improving tar yield

Liu, J. *et al. Fuel Processing Technology*, 2010, 91, (4), 419–423.

A new process to integrate coal pyrolysis with CO_2 reforming of methane over Ni/MgO catalyst was put forward for improving tar yield. And several Chinese coals were used to confirm the validity of the process. The experiments were performed in an atmospheric fixed-bed reactor containing upper catalyst layer and lower coal layer to investigate the effect of pyrolysis temperature, coal properties, Ni loading and reduction temperature of Ni/MgO catalysts on tar, water and char yields and CH_4 conversion at fixed conditions of 400 ml/min CH_4 flow rate, 1:1 CH_4/CO_2 ratio, 30 min holding time. The results indicated that higher tar yield can be obtained in the pyrolysis of all four coals investigated when coal pyrolysis was integrated with CO_2 reforming of methane. For PS coal, the tar, water and char yield is 33.5, 25.8 and 69.5 wt%, respectively and the CH_4 conversion is 16.8%, at the pyrolysis temperature of 750 °C over 10 wt% Ni/MgO catalyst reduced at 850 °C. The tar yield is 1.6 and 1.8 times as that in coal pyrolysis under H_2 and N_2, respectively.

11/00659 Investigation of the structural and reactants properties on the thermal characteristics of a premixed porous burner

Akbari, M. H. and Riahi, P. *Applied Energy*, 2010, 87, (4), 1433–1440.

Porous burners offer attractive features such as competitive combustion efficiency, high power ranges, and lower pollutant emissions. In the present study, the thermal characteristics of a porous burner are numerically investigated for a range of operating conditions and design specifications within a practical range. The premixed flame propagation of a methane/air mixture in a ceramic porous medium is simulated through an unsteady, one-dimensional model. The combustion process is modelled using a suitable single-step chemical kinetics. The reaction location is not predetermined, thus the flame is allowed to float within the solid matrix or to run off from either side of the porous medium. The numerical results indicate that flame stability and thermal characteristics of the burner are strongly dependent on the inlet mixture specifications and the solid matrix structural properties. For a fixed value of the inlet firing rate, the combustion products temperature will increase by an increase in the inlet gas temperature, an increase in the matrix porosity, or by a decrease of the matrix pore density. Among the geometrical properties, the burner length has virtually no effect on the burner performance. An increase in the solid matrix porosity or burner firing rate will increase the efficiency of the preheating zone, while increasing the inlet gas temperature or matrix pore density will cause a reduction in this efficiency. Simulation results also suggest that in order to prevent flame blow-out or flash-back, critical values of the burner settings and design parameters must be avoided.

11/00660 Investigation on fuel-rich premixed flames of monocyclic aromatic hydrocarbons: part I. Intermediate identification and mass spectrometric analysis

Li, Y. *et al. Combustion and Flame*, 2010, 157, (1), 143–154.

Fuel-rich premixed flames of seven monocyclic aromatic hydrocarbons (MAHs) including benzene, toluene, styrene, ethylbenzene, ortho-xylene, meta-xylene, and para-xylene were studied at the pressure of 30 torr and comparable flame conditions (C/O = 0.68). The measurement of photoionization efficiency (PIE) spectra facilitated the comprehensive identification of combustion intermediates from m/z = 15 to 240, while mass spectrometric analysis was performed to gain insight into the flame chemistry. Features of the side-chain structure in fuel molecule affect the primary decomposition and aromatics growth processes, resulting in different isomeric structures or compositions of some primary products. This effect becomes weaker and weaker as both processes proceed. The results indicate that most intermediates are identical in all flames, leading to similar intermediate pools of these fuels. Consequently the chemical structures of flames fuelled by different MAHs are almost identical, subsequent to the initial fuel-specific decomposition and oxidation that produce the primary intermediates. On the other hand, special features of the side-chain structure can affect the concentration levels of PAHs by increasing the concentrations of the key intermediates including the benzyl radical and phenylacetylene. Therefore, the total ion intensities of the PAH intermediates in the flames were observed to increase in the order of: benzene < toluene and styrene < four C_8H_{10}, which implies the same order of the sooting tendency.

11/00661 Modelling of grate combustion in a medium scale biomass furnace for control purposes

Bauer, R. *et al. Biomass and Bioenergy*, 2010, 34, (4), 417–427.

A new mathematical model for the grate combustion of biomass has been derived from physical considerations. Various models for grate combustion can already be found in the literature. Usually their intention is to simulate the real situation in a furnace as precisely as possible. Hence they are very detailed, typically consisting of many partial differential equations. However, because of their complexity they are useless for control purposes. The new model is very simple, consisting of only two ordinary differential equations, which makes it particularly suitable as a basis for model based control strategies. To verify the model, experiments were performed at a pilot scale furnace with horizontally moving grate. The pilot plant is a downscaled version (180 kW_{th}) of a typical medium scale furnace in terms of geometry and instrumentation. Comparison of the measured and calculated values shows good agreement.

11/00662 Multidimensional flamelet-generated manifolds for partially premixed combustion

Nguyen, P.-D. *et al. Combustion and Flame*, 2010, 157, (1), 43–61.

Flamelet-generated manifolds have been restricted so far to premixed or diffusion flame archetypes, even though the resulting tables have been applied to non-premixed and partially premixed flame simulations. By using a projection of the full set of mass conservation species balance equations into a restricted subset of the composition space, unsteady multidimensional flamelet governing equations are derived from first principles, under given hypotheses. During the projection, as in usual one-dimensional flamelets, the tangential strain rate of scalar isosurfaces is expressed in the form of the scalar dissipation rates of the control parameters of the multidimensional flamelet-generated manifold (MFM), which is tested in its five-dimensional form for partially premixed combustion, with two composition space directions and three scalar dissipation rates. It is shown that strain-rate-induced effects can hardly be fully neglected in chemistry tabulation of partially premixed combustion, because of fluxes across iso-equivalence-ratio and iso-progress-of-reaction surfaces. This is illustrated by comparing the five-dimensional flamelet-generated manifold with one-dimensional premixed flame and unsteady strained diffusion flame composition space trajectories. The formal links between the asymptotic behaviour of MFM and stratified flame, weakly varying partially premixed front, triple-flame, premixed and non-premixed edge flames are also evidenced.

11/00663 Nitrogen dilution effect on flame stability in a lifted non-premixed turbulent hydrogen jet with coaxial air

Oh, J. *et al. Fuel*, 2010, 89, (7), 1492–1498.

The nitrogen dilution effect on flame stability was experimentally investigated in a lifted non-premixed turbulent hydrogen jet with coaxial air. Hydrogen gas was used as the fuel and coaxial air was injected to initiate flame liftoff. Hydrogen was injected into an axisymmetric inner nozzle (d_F = 3.65 mm) and coaxial air jetted from an axisymmetric outer nozzle (d_A = 14.1 mm). The fuel jet and coaxial air velocities were fixed at u_F = 200 m/s and u_A = 16 m/s, while the mole fraction of the nitrogen diluent gas varied from 0.0 to 0.2 with a 0.1 step. For the analysis of the flame structure and the flame stabilization mechanism, the simultaneous measurement of PIV/OH PLIF was performed. The stabilization point was in the region of the flame base with the most upstream region and was defined as the point where the turbulent flame propagation velocity was found to be balanced with the axial component of the local flow velocity. The turbulent flame propagation velocity increased as the nitrogen mixture fraction decreased. The nitrogen dilution makes the flame structure more premixed. That is, the stabilization mechanism shifts from edge flame propagation based mechanism toward premixed flame propagation based mechanism. It was concluded that the turbulent flame propagation velocity was expressed as a function of the turbulent intensity and the axial strain rate, even though the mole fraction of the nitrogen diluent varied.

11/00664 Octanoic acid pyrolysis in a stainless-steel tube: what is the role of the coke formed on the wall?

Gornay, J. *et al. Journal of Analytical Applied Pyrolysis*, 2010, 87, (1), 78–84.

A way of upgrading waste cooking oils into usable products or energy is pyrolysis. Used cooking oils contain free fatty acids. Therefore, octanoic acid was selected as a model molecule to investigate the behaviour of carboxylic acid pyrolysis. The experiments were first performed in a stainless-steel reactor that obviously led to coke deposits on the wall. To analyse the effects of reaction temperature, residence time of the reactant, and composition of the wall material, octanoic acid pyrolysis was conducted in reactors made of different metals and with different internal diameters. The obtained results showed that, in addition to the significant effects of reactor wall itself, octanoic acid pyrolysis was catalysed by Fe, Ni, and Cr metal content of the coke formed at the initial stage of the reaction. Continuous analysis of CO, CO_2 and H_2 production throughout octanoic acid pyrolysis confirmed this result and showed that the coke formed in three stages during which it firstly acted as a pyrolysis accelerator with an activity decreasing with time, and then as a passivator-like agent. Hence, two types of coke were formed: first coke containing a certain amount of metal, then a non-metallic coke. Also, when using reactors of different construction materials, different types of coke deposits were observed demonstrating that coke deposition and activity depends on the surface metal content of the reactor. The conclusion of this work clearly confirms that reactors built of materials as chemically inert as possible (i.e. quartz) are a prerequisite to generate kinetic data aimed at validating or extending homogeneous gas phase kinetic models.

11/00665 On the influence of singlet oxygen molecules on the speed of flame propagation in methane–air mixture

Starik, A. M. *et al. Combustion and Flame*, 2010, 157, (2), 313–327.

The effect of the presence of singlet oxygen molecules $O_2(a^1\Delta_g)$ in a CH_4–air mixture on the speed of laminar flame propagation is considered. The known experimental data on the laminar flame speed and ignition delay are used to validate the developed kinetic model involving electronically excited oxygen molecules O_2 ($a^1\Delta_g$) and O_2 ($b^1\Sigma^+_g$). Numerical simulation shows that the presence of 10% $O_2(a^1\Delta_g)$ in molecular oxygen enables to increase significantly (by a factor of 1.7) the speed of flame propagation in a fuel-lean (ϕ = 0.45) methane–air mixture. The main reason for such an acceleration of flame propagation is the intensification of chain reactions due to addition of singlet delta oxygen molecules. For a fuel-rich mixture (ϕ = 1.9), the growth in the flame speed is significantly smaller and attains a factor of 1.4.

11/00666 Oxy-fuel combustion of solid fuels

Toftegaard, M. B. *et al. Progress in Energy and Combustion Science*, 2010, 36, (5), 581–625.

Oxy-fuel combustion is suggested as one of the possible, promising technologies for capturing CO_2 from power plants. The concept of oxy-fuel combustion is removal of nitrogen from the oxidizer to carry out the combustion process in oxygen and, in most concepts, recycled flue gas to lower the flame temperature. The flue gas produced thus consists primarily of carbon dioxide and water. Much research on the different aspects of an oxy-fuel power plant has been performed during the last decade. Focus has mainly been on retrofits of existing pulverized-coal-fired power plant units. Green-field plants which provide additional options for improvement of process economics are however likewise investigated. Of particular interest is the change of the combustion process induced by the exchange of carbon dioxide and water vapour for nitrogen as diluent. This paper reviews the published knowledge on the oxy-fuel process and focuses particularly on the combustion fundamentals, i.e. flame temperatures and heat transfer, ignition and burnout, emissions, and fly ash characteristics. Knowledge is currently available regarding both an entire oxy-fuel power plant and the combustion fundamentals. However, several questions remain unanswered and more research and pilot plant testing of heat transfer profiles, emission levels, the optimum oxygen excess and inlet oxygen concentration levels, high and low-temperature fire-side corrosion, ash quality, plant operability, and models to predict NO_x and SO_3 formation is required.

11/00667 Regeneration of spent catalysts in oxy-combustion atmosphere

Ammendola, P. *et al. Experimental Thermal and Fluid Science*, 2010, 34, (3), 262–268.

The feasibility of adopting an oxy-combustion stage to regenerate a spent catalyst proposed for methane thermo-catalytic decomposition has been investigated in a laboratory scale bubbling fluidized bed reactor operated at 800 °C and different inlet oxygen concentrations. The efficiency of carbon oxy-combustion regeneration strategy has been evaluated on the basis of the efficiency of carbon removed from the catalyst and the performance of regenerated catalyst. The effect of multiple cycles of decomposition and regeneration steps has been also quantified. Experimental activity confirmed the possibility of producing a carbon dioxide stream that can be finalized to a sequestration unit but also indicated the requirement of a good temperature control of catalytic particles.

11/00668 Temperature distribution within the moving bed of rotary kilns: measurement and analysis

Liu, X. Y. and Specht, E. *Chemical Engineering and Processing: Process Intensification*, 2010, 49, (2), 147–150.

Inadequacies in the temperature measurement within the moving bed have hindered a thorough understanding of the processes occurring within rotary kilns. A new measuring system, consisting of thermo-couple arrays, a radio-transmitter, a radio-receiver and a computer monitor is introduced in this paper. With it, the three-dimensional temperatures within the moving bed, as well as the temperatures of the freeboard gas and the kiln wall, can be measured and saved automatically. Experiments with sand on a co-current pilot kiln demonstrated that, in the passive layer of the moving bed, the temperatures were approximately constant in the circumferential direction. In the radial direction, however, large temperature difference was observed within the bed near the feed end of the kiln, and the difference became smaller as the bed went progressed through the kiln. This temperature measuring system can be used to obtain data over a wide range of operating conditions for use in engineering design. The obtained results may give new thoughts in theoretical modelling of heat transfer within the moving bed of rotary kilns.

11/00669 The influence of oxygen concentration on the combustion of a fuel/oxidizer mixture

Biteau, H. *et al. Experimental Thermal and Fluid Science*, 2010, 34, (3), 282–289.

The aim of the present study was to investigate the influence of the O_2 concentration on the combustion behaviour of a fuel/oxidizer mixture. The material tested is a ternary mixture of lactose, starch, and potassium nitrate, which has already been used in an attempt to estimate heat release rate using the FM-Global Fire Propagation Apparatus. It provides a well-controlled combustion chamber to study the evolution of the combustion products when varying the O_2 concentration, between air and low oxidizer conditions. Different chemical behaviours have been exhibited. When the O_2 concentration was reduced beyond 18%, large variations were observed in the CO_2 and CO concentrations. This critical O_2 concentration seems to be the limit before which the material only uses its own oxidizer to react. On the other hand, mass loss did not highlight this change in chemical reactions and remained similar whatever the test conditions. This presumes that the oxidation of CO into CO_2 are due to reactions occurring in the gas phase especially for large O_2 concentrations. This actual behaviour can be verified using a simplified flammability limit model adapted for the current work. Finally, a sensitivity analysis has been carried out to underline the influence of CO concentration in the evaluation of heat release rate using typical calorimetric methods. The results of this study provide a critical basis for the investigation of the combustion of a fuel/oxidizer mixture and for the validation of future numerical models.

11/00670 The motion of discs and spherical fuel particles in combustion burners based on Monte Carlo simulation

Granada, E. *et al. Energy Conversion and Management*, 2010, 51, (4), 795–801.

The position of pellet fuel particles in a burner largely determines their combustion behaviour. This paper addresses the simulated motion of circles and spheres, equivalent to pellet, and their final position in a

packed bed subject to a gravitational field confined inside rigid cylindrical walls. A simplified Monte Carlo statistical technique has been described and applied with the standard Metropolis method for the simulation of movement. This simplification provides an easier understanding of the method when applied to solid fuels in granular form, provided that they are only under gravitational forces. Three parameters are compared, these are radial, bulk and local porosities, via Voronoi tessellation. The simulations reveal a structural order near the walls, which declines towards the centre of the container, and no pattern was found in local porosity via Voronoi. Results with this simplified method are in agreement with more complex previously published studies.

11/00671 Transverse jets and their control
Karagozian, A. R. *Progress in Energy and Combustion Science*, 2010, 36, (5), 531–553.
The jet in crossflow or transverse jet has been studied extensively because of its relevance to a wide variety of flows in technological systems, including fuel or dilution air injection in gas turbine engines, thrust vector control for high speed airbreathing and rocket vehicles, and exhaust plumes from power plants. These widespread applications have led over the past 50± years to experimental, theoretical, and numerical examinations of this fundamental flowfield, with and without a combustion reaction, and with single or multi-phase flow. The complexities in this flowfield, whether the jet is introduced flush with respect to the injection wall or from an elevated pipe or nozzle, present challenges in accurately interrogating, analysing, and simulating important jet features. This review article provides a background on these studies and applications as well as detailed features of the transverse jet, and mechanisms for its control via active means. Promising future directions for the understanding, interrogation, simulation, and control of transverse jet flows are also identified and discussed.

Fire safety

11/00672 An experimental method for studying the discrete droplet impact phenomena in a flammable gas environment
Zhao, H. *et al. Journal of Natural Gas Science and Engineering*, 2010, 2, (5), 259–269.
To improve the initial design as well as to gain insight into operational issues of heat exchangers and other process equipment involving complex two-phase flow phenomena, one can choose to conduct full-scale tests. Another possibility, which is considered here, is to gain better and more detailed knowledge of the relevant two-phase flow phenomena, both by numerical and experimental studies. This article presents an experimental method for studying the droplet–pool impact phenomena in a flammable gas environment by using high-speed photography. The design of the test cell enables the integration of different parts which are responsible for phenomena generation, temperature and pressure measurements, and the cell can be operated in the gas-tight condition. In order to discretize the impact phenomena, the high impact frequency is reduced through a special design of an electrical 'shutter'. Targeted safety measures are employed in the experiment. Two regimes of *n*-pentane droplets impacting with a deep pool of the same fluid are identified. Experiments have also been conducted with distilled water and air, for reference. It is found that the flow of *n*-pentane is more agitated than that of distilled water, and that in a similar diameter range, the transition from coalescence to jetting of *n*-pentane occurs at a lower velocity level than for water. The main reason for this more agitated flow condition is the low viscosity and surface tension of *n*-pentane.

11/00673 Defining the effects of ambient conditions in large-scale fire tests
Tamanini, F. *Experimental Thermal and Fluid Science*, 2010, 34, (3), 404–411.
The paper documents the results of an analysis of the effects of ambient conditions, temperature and relative humidity, on the development of large-scale fires during their initial growth. While the study has focused on the behaviour of hygroscopic cartoned commodities, because their burning behaviour is greatly affected by propensity to absorb ambient moisture, non-hygroscopic materials and their reduced sensitivity to ambient humidity could also be considered. The analysis introduces the heat release rate at the time of first sprinkler activation as a meaningful measure to represent the impact of ambient conditions on the development of a free-burning fire. The next step of estimating the behaviour under extinguishment conditions is not possible at this time, though general considerations on expected trends are offered on the basis of the results obtained from another research program. The practical output of the work is in the form of the identification of the desirable range of operating conditions for ambient temperature and relative humidity in large-scale fire testing.

11/00674 Numerical study of hydrogen explosions in a refuelling environment and in a model storage room
Wen, J. X. *et al. International Journal of Hydrogen Energy*, 2010, 35, (1), 385–394.
Numerical simulations have been carried out for large-scale hydrogen explosions in a refuelling environment and in a model storage room. For the first scenario, a high pressure hydrogen jet released in a congested refuelling environment was ignited and the subsequent explosion analysed. The computational domain mimics the experimental set up for a vertical downwards release in a vehicle refuelling environment experimentally tested previously. For completeness of the analysis, an analytical model has also been developed to provide the transient pressure conditions at nozzle exit. The numerical study is based on the traditional computational fluid dynamics techniques solving Reynolds averaged Navier-Stokes equations. The pseudo diameter approach is used to bypass the shock-laden flow structure in the immediate vicinity of the nozzle. For combustion, the turbulent flame closure model is used while the shear stress transport model is used for turbulence. In the second scenario, premixed hydrogen-air clouds with different hydrogen concentrations from 15% to 60% in volume were ignited in a model storage room. Analysis was carried out to derive the dependence of overpressure on hydrogen concentrations for safety considerations.

11/00675 On the occurrence of thermal explosion in a reacting gas: the effects of natural convection and consumption of reactant
Liu, T.-Y. *et al. Combustion and Flame*, 2010, 157, (2), 230–239.
Whether or not a chemical reaction in a fluid leads to an explosion is shown to depend on four timescales: that for the chemical reaction to heat up the fluid containing the reactants and products, for heat conduction out of the reactor, for natural convection in the fluid, and finally for chemical reaction. This approach is developed for an irreversible, *n*th-order chemical reaction, $A \rightarrow B$ occurring exothermically in a closed spherical vessel, whose wall is held at a fixed temperature. These four timescales are expressed in terms of the physical and chemical parameters of the system. A new three-dimensional regime diagram is proposed, in which the three effects inhibiting explosion, namely the consumption of reactant, and heat removal both by thermal conduction and by natural convection, appear separately. Numerical simulations are performed for laminar natural convection occurring, so that the development of temperature, composition and velocity throughout a reacting gas is computed for increasing times. The results are compared with previous experimental measurements in the gas phase for the decomposition of azomethane. The criterion for an explosion is considered in some detail; it appears that these systems explode if and when the maximum dimensionless rise in temperature exceeds a value close to 5.

11/00676 Radiant heat from propane jet fires
Gómez-Mares, M. *et al. Experimental Thermal and Fluid Science*, 2010, 34, (3), 323–329.
Sonic propane jet fire experiments were carried out in absence of wind, with visible flame length ranging between 2.2 and 8.1 m. The thermal radiation intensity increased with the mass flow rate and the flame length. The net heat released was also computed and a correlation for the flame length as a function of Q is proposed. The surface emissive power and the fraction of heat irradiated were estimated by applying the solid flame model, assuming the flame to be a cylinder. The variation of the emissive power as a function of flame length was found to follow a linear equation. The fraction of heat irradiated, η, was obtained from the value of the total radiative power; its average value for sonic propane gas flames was 0.07.

11/00677 Rapid prototyping of the central safety system for nuclear risk in ITER
Scibile, L. *et al. Fusion Engineering and Design*, 2010, 85, (3–4), 545–548.
The central safety system for nuclear risk (CSS-N) coordinates the safety control systems to ensure nuclear safety for the International Thermonuclear Experimental Reactor (ITER) complex. Since the CSS-N is a safety critical system, its validation and commissioning play a very important role; in particular the required level of reliability must be demonstrated. In such a scenario, it is strongly recommended to use modelling and simulation tools since the early design phase. Indeed, the modelling tools will help in the definition of the control system requirements. Furthermore the models can than be used for the rapid prototyping of the safety system. Hardware-in-the-loop simulations can also be performed in order to assess the performance of the control hardware against a plant simulator. The proposed approach relies on the availability of a plant simulator to develop the prototype of the

control system. This paper introduces the methodology used to design and develop both the CSS-N oriented plant simulator and the CSS-N prototype.

09 PROCESS HEATING, POWER AND INCINERATION

Energy applications in industry

11/00678 CFD–DEM simulation of gas–solid reacting flows in fluid catalytic cracking (FCC) process

Wu, C. *et al. Chemical Engineering Science*, 2010, 65, (1), 542–549.

The CFD–DEM coupled approach was used to simulate the complex gas–solid reacting flows in fluid catalytic cracking (FCC) processes accommodated in riser or downer reactors. Considering the solid catalysed gas-phase reactions, the model particularly incorporated the descriptions for heat transfer behaviours between particles and between gas and particles, the instantaneous catalyst deactivation, and the lumped kinetics in the gas phase for the FCC process, together with the governing equations for the hydrodynamics. The distinct advantage of the present approach is that the catalyst activity can be calculated in time by tracking the history of the particle movement with the occurrence of heat transfer and chemical reactions. The simulation results captured the major features of the FCC process very well either in riser or in downer, which had reasonable agreement with the experimental data in the literature. The reduced selectivity to the desired intermediate products in risers, especially under high catalyst to oil ratios, can be clearly understood from the simulated back-mixing behaviour of solid catalysts and the deactivation of catalysts at different locations in the reactor, which caused the non-ideal reaction progress inside the reactor space. It can be concluded that this type of modelling approach forms a solid basis for the cross-scale modelling of general multi-phase catalytic reacting flows.

11/00679 Design and optimization of a non-TEMA type tubular recuperative heat exchanger used in a regenerative gas turbine cycle

Sayyaadi, H. and Aminian, H. R. *Energy*, 2010, 35, (4), 1647–1657.

A special non-TEMA type tubular recuperative heat exchanger used as a regenerator of a gas turbine cycle is considered for multi-criteria optimization. It is assumed that the recuperator is designed for an existing gas turbine cycle to be retrofitted. Three scenarios for optimization of the proposed system have been considered. In one scenario, the objective is minimizing the cost of recuperator; while in another scenario maximizing the cycle exergetic efficiency is considered. In third scenario, both objectives are optimized simultaneously in a multi-objective optimization approach. Geometric specification of the recuperator including tubes length, tubes outside/inside diameters, tube pitch in the tube bundle, inside shell diameter, outer and inner tube limits of the tube bundle and the total number of disc and doughnut baffles are considered as decision variables. Combination of these objectives and decision variables with suitable engineering and physical constraints (including NO_x and CO emission limitations) makes a set of *MINLP* optimization problem. Optimization programming in MATLAB is performed using one of the most powerful and robust multi-objective optimization algorithms namely *NSGA-II*. This approach which is based on the genetic algorithm is applied to find a set of Pareto optimal solutions. Pareto optimal frontier is obtained and a final optimal solution is selected in a decision-making process. It is shown that the multi-objective optimization scenario can be considered as a generalized optimization approach in which balances between economical viewpoints of both heat exchanger manufacturer and end user of recuperator.

11/00680 Effects of design features on combustion efficiency and emission performance of a biomass-fuelled fluidized-bed combustor

Sirisomboon, K. *et al. Chemical Engineering and Processing: Process Intensification*, 2010, 49, (3), 270–277.

This paper presents an analysis of some measures leading to intensification of the combustion process in a biomass-fuelled fluidized-bed combustor with a cone-shape bed (or 'conical FBC'). Two combustors firing rice husks with elevated fuel-ash content were the focus of this study. Compared to the pilot 350-kW_{th} conical FBC exhibiting combustion efficiency of up to 96%, the newly constructed 400-kW_{th} combustor included geometrical and design modifications aimed at improving the combustion efficiency and emission performance of the reactor. Differences between the air distributors and Δp–u diagrams (accounting for the total pressure drop across the air distributor and gas–solid fluidized bed) for the two reactors are discussed. Axial temperature and gas concentration (O_2, CO and NO_x) profiles in the combustors were compared for similar operating conditions (excess air and heat release rate per unit cross-sectional area). At excess air of 40–60%, the bed temperature in the advanced conical FBC was substantially, by about 180 °C, higher than that in the pilot combustor, mainly, due to better fuel–air mixing and higher residence time of reactants. The formation and decomposition of CO and NO in the bed region as well as in the freeboard of these two combustors showed quite different trends under similar operating conditions. At excess air of 40–60%, the CO emission from the advanced conical FBC was found to be much (seven to eight times) lower than that from the pilot combustor, while the NO_x emissions were represented by almost the same values. High (over 99%) combustion efficiency was achieved when firing rice husk in the advanced 400 kW_{th} conical FBC for the range of excess air.

11/00681 Gas holdup and bubble dynamics in a three-phase internal loop reactor with external slurry circulation

Zhang, K. *et al. Fuel*, 2010, 89, (7), 1361–1369.

As modified three-phase fluidized reactors, loop reactors have been widely used in the area of chemical and energy processes. An external slurry circulation is introduced into a traditional internal loop reactor to improve the transfer between gas and slurry phases. Gas holdup and bubble dynamics are investigated by using the double-sensor conductivity probe technique in the present work. The results show that gas holdup inside the draft tube is greatly affected by the geometrical configuration and is much higher than that in the corresponding section of the annular region. Local, section-averaged, and overall gas holdups increase with increasing superficial gas velocity, while the effects of solid loading and external slurry circulation velocity are less significant than that of superficial gas velocity. Both local bubble size and bubble rise velocity vary significantly in different regions.

11/00682 Gas turbine combustion performance test of hydrogen and carbon monoxide synthetic gas

Lee, M. C. *et al. Fuel*, 2010, 89, (7), 1485–1491.

The development of coal IGCC (integrated gasification combined cycle) technology has made it possible to exploit electricity generated from coal at a low cost. Furthermore, IGCC is a pre-requisite for the development of CCS (carbon capture and storage) technology and hydrogen generated from coal. To achieve the need to reduce CO_2 emissions, Korea's 300 MW IGCC RDD&D (Research Development, Demonstration and Dissemination) project was launched in December 2006 under the leadership of the Korea Electric Power Corporation (KEPCO), with the support of the Korea Ministry of Knowledge Economy. When a new fuel is adapted to a gas turbine (such as syngas for IGCC), it is necessary to study the gas turbine combustion characteristics of the fuel, because gas turbines are very sensitive to its physical and chemical properties. This experimental study was conducted by investigating the combustion performance of synthetic gas, which is composed chiefly of hydrogen and carbon monoxide. The results of a test on synthetic gas combustion performance were compared with the results of methane combustion, which is a major component of natural gas. The results of the combustion test of both gases were examined in terms of the turbine's inlet temperature, combustion dynamics, emission characteristics, and flame structure. The results of this experimental study provide an understanding of the combustion characteristics of synthetic gas and anticipate the problems when synthetic gas rather than natural gas is fuelled to a gas turbine.

11/00683 Gas-fired power plants: investment timing, operating flexibility and CO_2 capture

Fleten, S.-E. and Näsäkkälä, E. *Energy Economics*, 2010, 32, (4), 805–816.

This study analysed investments in gas-fired power plants based on stochastic electricity and natural gas prices. A simple but realistic two-factor model was used for price processes, enabling analysis of the value of operating flexibility, the opportunity to abandon the capital equipment, as well as finding thresholds for energy prices for which it is optimal to enter into the investment. A method was developed to compute upper and lower bounds on plant values and investment threshold levels. The case study used representative power plant investment and operations data, and historical forward prices from well-functioning energy markets. It was found that when the decision to build is considered, the abandonment option does not have significant value, whereas the operating flexibility and time-to-build option have significant effect on the building threshold. Furthermore, the joint value of the operating flexibility and the abandonment option is much

smaller than the sum of their separate values, because both are options to shut down. The effects of emission costs on the value of installing CO_2 capture technology are also analysed.

11/00684 Hydrogen production by auto-thermal chemical-looping reforming in a pressurized fluidized bed reactor using Ni-based oxygen carriers

Ortiz, M. *et al. International Journal of Hydrogen Energy*, 2010, 35, (1), 151–160.

This work presents the experimental results obtained during auto-thermal chemical-looping reforming (CLRa) in a semicontinuous pressurized fluidized bed reactor working with two Ni-based oxygen carriers and using methane as fuel. During operation the effect of the total pressure, reduction reaction temperature, and oxygen carrier-to-fuel molar ratio on CH_4 conversion, gas outlet concentrations, and carbon formation was analysed. In the range of pressures analysed (up to 10 bars), it was found that an increase in the total operating pressure did not produce a negative effect on the gas product distribution obtained in the process. At all operating pressures the CH_4 conversion was very high (>98%) and no carbon formation was detected. The most important variable affecting the gas product distribution was the solid circulation rate, that is, the oxygen carrier-to-fuel molar ratio (NiO/CH_4). The oxygen carriers were physically and chemically characterized by several techniques before and after using in the pressurized fluidized bed reactor. Important changes in the surface texture and the solid structure of the oxygen carrier particles were not detected. These results suggest that these oxygen carriers could have a high durability, making them suitable for use in a pressurized CLRa system.

11/00685 Identification of stable operating ranges of a counter-current multistage fluidized bed reactor with downcomer

Mohanty, C. R. *et al. Chemical Engineering and Processing: Process Intensification*, 2010, 49, (1), 104–112.

This paper describes the stable operating range for a multistage gas–solid fluidized bed reactor and the influence of downcomer and aspect ratio on stable and uniform gas–solid fluidization. A three-stage counter-current fluidized bed reactor was designed, fabricated and operated and range of stable operation for lime and sand particles has been determined. In addition to that a comprehensive discussion on dynamics of downcomer has been made to ensure smooth transfer of solids from one stage to another. A theoretical model has been developed to predict the solid height in downcomer and tested for experimental conditions. The influence of aspect ratio on distributor to bed ratio (P_p/P_b) was investigated for the reactor for uniform fluidization.

11/00686 Linear stability analysis of gas-fluidized beds for the prediction of incipient bubbling conditions

Busciglio, A. *et al. Chemical Engineering Journal*, 2010, 157, (2–3), 489–500.

This work focuses on the development of a novel linear stability criterion for the state of homogeneous fluidization regime, based on a new mathematical model for gas-fluidized beds. The model is developed starting from the well-known particle bed model. A mono-dimensional momentum balance is derived leading to a set of equations which explicitly include voidage-gradient dependent terms (elastic force) for both solid and fluid phases. A fully predictive criterion for the stability of homogeneous fluidization state is here proposed, based on the well-known Wallis' linear stability analysis. The criterion requires the choice of an appropriate averaging distance, which in the present development is found to be bed-voidage dependent. The linear stability criterion resulted in turn in a simple, yet fully predictive, relationship for incipient bubbling voidage. Validation was carried out analysing the influence of all physical properties and sensitivity to closure relations, showing substantial agreement with the existing literature data.

11/00687 Liquor flow in a model kraft batch digester

Lee, Q. F. and Bennington, P. J. *Chemical Engineering Journal*, 2010, 158, (1), 51–60.

Batch digesters are solid–liquid reactors used to produce chemical pulp from wood chips. The literature shows that the extent of reaction (delignification) varies as a function of chip location in the vessel, with the extent of non-uniformity commonly attributed to poor and/or non-uniform liquor flow through the digester (which causes poor chemical and heat distribution through the chip mass during the cook). Electrical resistance tomography (ERT) was used to evaluate the uniformity of liquor flow in a laboratory scale-model digester (a 1:15 geometrically scaled vessel) with model particles used in place of wood chips (the vessel-to-particle diameter ratio was 93:1 to minimize wall effects) and close approximation of the liquor superficial velocity and pore Reynolds number. Local flow velocities were also measured for common flow conditions using ERT data and pixel–pixel cross-correlation techniques, with the results compared with computational simulations made using a commercial CFD code. The tomographic data shows that it is possible to create uniform zones in the digester, although a stagnation point exists in the centre of the vessel at the screen level. This point coincides with the location of highest kappa numbers (the lowest extent of reaction) reported in industrial tests. Within the resolution of the tomographic technique local axial flow velocities were found to agree with calculated and computational results. The flow velocity data were used as input to a two-dimensional, mathematical model of reaction within the digester, with the variability of lignin distribution compared to available industrial data.

11/00688 Long-term coal gasification-based power plants with near-zero emissions. Part A: Zecomix cycle

Romano, M. C. and Lozza, G. G. *International Journal of Greenhouse Gas Control*, 2010, 4, (3), 459–468.

Three plant configurations are analysed for high efficiency, near-zero emissions power generation from coal, suitable for long-term installations. The Zecomix cycle, a novel power plant based on various innovative processes, is presented. The Zecomix plant is based on a coal hydrogasification process, using recycled steam and hydrogen as gasifying agents, to produce a CH_4 rich syngas. Methane is then converted to an H_2/H_2O based syngas and CO_2 is captured, by reacting in two carbonator reactors with CaO-based solid sorbent. $CaCO_3$ produced in carbonators is thermally regenerated in a calciner. The synthetic fuel is burned with oxygen in a semi-closed high temperature steam cycle, with a supercritical heat recovery. The paper presents a detailed analysis of the thermodynamic aspects of the process, with the scope of assessing its potential performance in terms of efficiency and emissions. Main operating parameters of the chemical island (e.g. hydrogasifier and calciner pressure, steam flow rates to carbonators, syngas recycle fraction) and of the power island (e.g. pressure ratio, turbine inlet temperature and reheat pressure) were varied in order to evaluate their effect on plant performance and to optimize the process. Critical issues are specifically discussed: the calcination process, the calcium oxide utilization in carbonators, the cooling requirement of the high temperature turbine, the presence of incondensable species in the steam cycle. An accurate performance estimation is therefore developed by considering advanced components, as an evolution of today's technology, excluding unproven devices whose feasibility cannot be anticipated. Depending on sorbent utilization, a net plant efficiency of 44–47% with a virtually complete carbon capture was obtained, a very interesting result with respect to other proposed coal-fired power plants with carbon capture. The high complexity of the chemical island and the importance of a good sorbent performance should be however taken into account for a fair comparison with other plant concepts. Further experimental investigations are mandatory to demonstrate the technical and economical feasibility of the Zecomix plant.

11/00689 Long-term coal gasification-based power with near-zero emissions. Part B: Zecomag and oxy-fuel IGCC cycles

Romano, M. C. and Lozza, G. G. *International Journal of Greenhouse Gas Control*, 2010, 4, (3), 469–477.

Two long-term technologies for power generation from coal are investigated. The Zecomag plant has the same syngas production system of the Zecomix plant, but hydrogen-rich syngas is here burned with air in an open-cycle gas turbine. The aim is a simplification of the power island, more similar to a combined cycle; however, CO_2 capture falls from 100% to about 90% and NO_x emissions are present. An advanced oxy-fuel IGCC is the second plant investigated in this paper, presenting the same zero-emission potential of Zecomix. Syngas is produced in a high pressure, dry feed, oxygen blown gasifier and cleaned in a hot-gas-clean-up system. Clean syngas is then burned with oxygen and expanded in a turbine, using compressed recirculated CO_2 to moderate firing temperature and to cool turbine blades. The loss of net efficiency, with respect to Zecomix, is very limited (1–2 points) with both configurations. In order to better evaluate the performances obtained, a comparison with reference state-of-the art IGCCs and a long-term IGCC without CO_2 capture is also presented.

11/00690 Microreactor numbering-up in multi-scale networks for industrial-scale applications: impact of flow maldistribution on the reactor performances

Saber, M. *et al. Chemical Engineering Science*, 2010, 65, (1), 372–379.

The performance of multi-scale networks is investigated considering the selectivity of consecutive catalytic reactions occurring at the coated walls of the parallel microchannels. The impact of the channel arrangement on the global performance of the network is analysed. It is shown that controlling the flow uniformity through the parallel channels can result in the improvement of the overall reaction selectivity, while simultaneously reducing the overall pressure drop through the network. The robustness of such networks is also analysed through a channel clogging simulation.

11/00691 On-line transient stability assessment of large-scale power systems by using ball vector machines

Mohammadi, M. and Gharehpetian, G. B. *Energy Conversion and Management*, 2010, 51, (4), 640–647.

The paper ball vector machine (BVM) has been used for on-line transient stability assessment of large-scale power systems. To classify the system transient security status, a BVM has been trained for all contingencies. The proposed BVM based security assessment algorithm has very small training time and space in comparison with artificial neural networks (ANN), support vector machines (SVM) and other machine learning based algorithms. In addition, the proposed algorithm has less support vectors (SV) and therefore is faster than existing algorithms for on-line applications. One of the main points, to apply a machine learning method is feature selection. In this paper, a new decision tree (DT)-based feature selection technique has been presented. The proposed BVM based algorithm has been applied to the New England 39-bus power system. The simulation results show the effectiveness and the stability of the proposed method for on-line transient stability assessment procedure of large-scale power system. The proposed feature selection algorithm has been compared with different feature selection algorithms. The simulation results demonstrate the effectiveness of the proposed feature algorithm.

11/00692 Prospects for cost-effective post-combustion CO_2 capture from industrial CHPs

Kuramochi, T. *et al. International Journal of Greenhouse Gas Control*, 2010, 4, (3), 511–524.

Industrial combined heat and power plants (CHPs) are often operated at partial load conditions. If CO_2 is captured from a CHP, additional energy requirements can be fully or partly met by increasing the load. Load increase improves plant efficiency and, consequently, part of the additional energy consumption would be offset. If this advantage is large enough, industrial CHPs may become an attractive option for CO_2 capture and storage CCS. The authors therefore investigated the technoeconomic performance of post-combustion CO_2 capture from small-to-medium-scale (50–200 MWe maximum electrical capacity) industrial natural gas combined cycle (NGCC) CHPs in comparison with large-scale (400 MWe) NGCCs in the short term (2010) and the mid-term future (2020–2025). The analysed system encompasses NGCC, CO_2 capture, compression, and branch CO_2 pipeline. The technical results showed that CO_2 capture energy requirement for industrial NGCC-CHPs is significantly lower than that for 400 MWe NGCCs: up to 16% in the short term and up to 12% in the mid-term future. The economic results showed that at low heat-to-power ratio operations, CO_2 capture from industrial NGCC-CHPs at 100 MWe in the short term (41–44 €/tCO_2 avoided) and 200 MWe in the mid-term future (33–36 €/tCO_2 avoided) may compete with 400 MWe NGCCs (46–50 €/tCO_2 avoided short term, 30–35 €/tCO_2 avoided mid-term).

11/00693 Pyrolysis of a fraction of waste polypropylene and polyethylene for the recovery of BTX aromatics using a fluidized bed reactor

Jung, S.-H. *et al. Fuel Processing Technology*, 2010, 91, (3), 277–284.

Fractions of waste polypropylene and polyethylene were pyrolysed in a pyrolysis plant under different conditions. In this study, the influence of the reaction temperature (650–750 °C), the feed rate, and the kind of fluidizing medium on the product spectrum were investigated. Pyrolysis of the PP fraction produced oils up to 43 wt. % of the product. With respect to the PE fraction, the maximum oil yield was above 60 wt% of the product. The target compound was BTX aromatics, whose amount in the oils reached 53 wt% for the PP fraction and 32 wt% for the PE fraction. It was shown that the PE fraction yielded a higher liquid product compared to the PP fraction, and that the concentration of aromatics in the oil increased at higher reaction temperatures for both the PP and PE fractions. A higher feed rate and the use of a gas product as the fluidizing medium were favoured for the production of oils for both the PP and PE fractions. The oils that were obtained in the experiments almost had no metal and chlorine contents. The maximum heating value of the gas obtained in the experiments was about 50 MJ/kg.

11/00694 Recovery of 1-butanol from aqueous solutions using zeolite ZSM-5 with a high Si/Al ratio; suitability of a column process for industrial applications

Saravanan, V. *et al. Biochemical Engineering Journal*, 2010, 49, (1), 33–39.

Commercially available zeolites (CBV28014, CBV901) with a high Si/Al ratio were tested as adsorbents to recover 1-butanol from aqueous solutions such as acetone–butanol–ethanol (ABE) fermentation broth. It was found that these zeolites can quickly and almost completely adsorb 1-butanol from aqueous solutions containing approximately 1 wt% of 1-butanol. The binding capacity of the zeolites appeared to be around 0.12 g 1-butanol/g zeolite, and remained constant until equilibrium concentration as low as 0.04 wt% 1-butanol in water. Extrudates were prepared and tested in a column set-up to get an impression of the suitability of these zeolites for industrial applications. Extrudates of 80% zeolite and 20% alumina binder with 16–24 mesh (0.7–1.0 mm) size showed the best adsorption results in a packed bed column with up-flow of ABE broth. The adsorbent loading at 10% breakthrough was calculated to be 0.085 g 1-butanol/g zeolite (9.3 min residence time). A subsequent temperature swing leads to desorption. By choosing the temperature program carefully, it was possible to separate the water/ethanol/acetone and 1-butanol fractions. The resulting 1-butanol concentration in the 1-butanol fraction was 84.3 wt% and thus a concentration factor of 65 was achieved in one step, which is a higher value compared to other isolation techniques. Only 80% of adsorbed 1-butanol could be recovered, the remainder could only be desorbed at higher temperatures as butene. However, this should not be a problem in an industrial process as all stronger binding, catalytic sites will be blocked after the first adsorption/desorption round. A mathematical model was developed to simulate the breakthrough data and a mass transfer coefficient ($k_p a$) of $0.052\,min^{-1}$ was obtained. Comparison of simulated $k_p a$ for different sizes of extrudates clearly indicated that the adsorption rate is determined by solid phase diffusion.

11/00695 Relationship between flow structure and transfer coefficients in fast fluidized beds

Hou, B. and Li, H. *Chemical Engineering Journal*, 2010, 157, (2–3), 509–519.

In this paper, the relationships between the bed structural parameters and momentum transfer, mass transfer and heat transfer in fast fluidized beds are analysed for Geldart A or B particles. The influence of dispersion and aggregation of particles on the mass transfer coefficient and heat transfer coefficient is discussed. The equations for calculating the drag force coefficient, mass transfer coefficient and heat transfer coefficient in fast fluidized beds are developed based on eight structural parameters (U_{fd}, U_{fc}, U_{pd}, U_{pc}, d_c, f, ε_d and ε_c) of heterogeneous beds, which can be solved by the energy-minimization multi-scale model. The drag force has been calculated based on the local bed structural parameters and the calculated solids flux and solids concentration are compared with the experimental data in the literature. For the heat transfer and mass transfer, the averaged bed structural parameters are employed to calculate the averaged heat transfer and mass transfer coefficients, and the results are compared with the experimental data from the literature. The simulating results are in good agreement with experimental data.

11/00696 Remaining life assessment and optimal design of statically indeterminate pipe system with circumferential crack

Liu, S.-P. *International Communications in Heat and Mass Transfer*, 2010, 37, (3), 266–273.

This paper examines the J–R curve theory in elastic-plastic fracture mechanics and crack extension resistance in order to analyse the large-scale yielding of statically indeterminate pipe structure with a circumferential crack. The dJ/da characteristic can be utilized to measure that the crack is stable ductile fracture or unstable ductile fracture and to analyse the crack growth rate. The total propagation time of the crack until collapse can be computationally estimated by numerical analysis that is presented in this paper. The further analysis of dJ/da and optimization is to maximize the crack propagation time during the crack growth before reaching plastic collapse. Both of the centre-point crack and end-point crack are investigating cases for analysing the mechanics and engineering design. These analysis and design strategies developed in this paper are useful for the safety performance of a structural pipe under crack deformation.

11/00697 Simulation of an industrial riser for catalytic cracking in the presence of coking using single-event microkinetics

Quintana-Solórzano, R. *et al. Catalysis Today*, 2010, 150, (3–4), 319–331.

A relumped single-event microkinetic model for the catalytic cracking of hydrocarbons and coke formation on a RE-USY equilibrium catalyst was used to simulate an industrial riser. In contrast to previous publications on the modelling of riser reactors for catalytic cracking, the current mode includes a fundamental description of the reaction pathway to catalytic coke, resulting in a slightly higher number of lumps, i.e. 677 + 1 for coke rather than 670. Coke formation occurs via alkylation of diaromatics and triaromatics, which are coke precursors formed during cracking or contained in the feed, with alkenes in liquid petroleum gas (LPG) and gasoline fractions. A one-dimensional reactor model which is pseudo-homogeneous with respect to concentrations but heterogeneous with respect to temperature was used. Feed conversion as well as LPG, gasoline and coke yield profiles along the riser position are in line with published results showing a vigorous cracking and a moderate to fast coke deposition in the first metres. For a riser of 30 m length, about 70% of the cracked product yields and feed conversion was established during the first 3 m. The effect of

operating conditions, feed composition and riser dimensions on the product distributions is assessed. The regenerated catalyst temperature and the catalyst to oil ratio are identified as the key operating parameters affecting the conversion and the cracked product distributions.

11/00698 Simulation of emission performance and combustion efficiency in biomass fired circulating fluidized bed combustors

Gungor, A. *Biomass and Bioenergy*, 2010, 34, (4), 506–514.

In this study, the combustion efficiency and the emission performance of biomass fired CFBs are tested via a previously published 2D model against two published comprehensive data sets. The model efficiently simulates the outcome with respect to the excess air values, which is the main parameter that is verified. The combustion efficiency of OC changes between 82.25 and 98.66% as the excess air increases from 10 to 116% with the maximum error of about 8.59%. The rice husk combustion efficiency changes between 98.05 and 97.56% as the bed operational velocity increases from 1.2 to 1.5 $m\,s^{-1}$ with the maximum error of about 7.60%. CO and NO_x emissions increase with increasing bed operational velocity. Increasing excess air results in slightly higher levels of NO_x emission. A significant amount of combustion occurs in the upper zone due to the high volatile content of the biomass fuels.

11/00699 Strategic simulation of the energy management in a Kraft mill

Cakembergh-Mas, A. *et al. Energy Conversion and Management*, 2010, 51, (5), 988–997.

The economic assessment of an energy enhancement program envisaged for a Kraft wood pulping mill has been performed. The retrofit projects which have been analysed include reduction of the process steam demand, steam exportation to a district heating network and cogeneration. An automated MILP optimization model has been developed to quantify the economic benefit of the projects independently and in combinations. Three cogeneration systems were considered: single back-pressure steam turbine, single steam condensing turbine and, a two-turbine system. A sensitivity analysis has been conducted for two modalities of key cost parameters (steam demand reduction level, fuel and power purchase costs, steam and power sales price) to determine the impact of those parameters on the economics of co-generation options. Results show that the configuration with the single back-pressure steam turbine has the shortest payback time, but the combination of two turbines produces more power and gives higher benefits in the long term.

11/00700 Supersonic attrition nozzles in gas–solid fluidized beds

Cruz, N. *et al. Chemical Engineering and Processing: Process Intensification*, 2010, 49, (3), 225–234.

Gas–solid fluidized beds are used in both catalytic and non-catalytic processes, and some of the industrial applications are fluid catalytic cracking, polyethylene production, drying and classification, coating, and granulation. In some applications, the size distribution of the bed particles must be controlled in order to maintain good fluidization, and attrition nozzles can be used for this purpose. Supersonic attrition nozzles are more efficient than subsonic nozzles, and, in this study, different geometries of the Laval nozzle, a convergent–divergent (C–D) nozzle, have been investigated. The geometry of this type of nozzles gives supersonic velocities under the right operating conditions. The attrition or grinding efficiency defined as the new surface area created by mass of attrition gas used, has been experimentally measured under a variety of operating conditions and the supersonic attrition nozzles have been optimized to reduce consumption of the attrition gas. Attrition nozzle pressures used during experimentation varied between 138 and 2550 kPa, and the effects of the gas properties were studied by using different attrition gases, including air, helium, a mixture of helium and nitrogen (0.82:0.18), argon, and carbon dioxide. Depending on shape of the divergent section in the nozzle, the results show that the grinding efficiency changes, and that this efficiency is related to the thrust (F) and equivalent velocity (U_{eq}) of the supersonic nozzle. This finding applies to different attrition gases, nozzle sizes and geometries. All the experiments were performed using silica sand particles with the same initial size distribution. The mass of the bed of silica sand was kept constant, as well as the fluidization velocity.

11/00701 The influence of temperature on limestone sulfation and attrition under fluidized bed combustion conditions

Montagnaro, F. *et al. Experimental Thermal and Fluid Science*, 2010, 34, (3), 352–358.

The influence of temperature on attrition of two limestones during desulfurization in a fluidized bed reactor was investigated. Differences in the microstructure of the two limestones were reflected by a different thickness of the sulfate shell formed upon sulfation and by a different value of the ultimate calcium conversion degree. Particle attrition and fragmentation were fairly small under moderately bubbling fluidization conditions for both limestones. An increase of temperature from 850 to 900 °C led to an increase of the attrition rate, most likely because of a particle weakening effect caused by a faster CO_2 evolution during calcination. This weakening effect, however, was not sufficiently strong to enhance particle fragmentation in the bed. The progress of sulfation, associated to the build-up of a hard sulfate shell around the particles, led in any case to a decrease of the extent of attrition. Sulfation at 900 °C was less effective than at 850 °C, and this was shown to be related to the porosimetric features of the different samples.

11/00702 Thermodynamic analysis of a power cycle using a low-temperature source and a binary NH_3–H_2O mixture as working fluid

Roy, P. *et al. International Journal of Thermal Sciences*, 2010, 49, (1), 48–58.

Two Rankine cycles, one with and one without a regenerator, both using a NH_3–H_2O mixture as the working fluid, have been analysed for fixed source and sink inlet temperatures. A fixed mass flow rate of a hot gaseous stream is providing the thermal energy input at the heat recovery boiler (HRB). The methodology used in this work is divided in four steps: energy analysis, exergy analysis, finite size (or finite time) thermodynamics (i.e. thermodynamic calculations in the context of reasonable temperature differences in the heat exchangers) and calculation of the heat exchangers' areas. The results show that the range of evaporation pressures satisfying some basic conditions increases with the source inlet temperature and with the ammonia concentration. They also show the existence of an optimum evaporation pressure for each of the four analyses. In the first two analyses, an optimum evaporation pressure of approximately 3.2 MPa maximizes the thermal and exergetic efficiency, at respectively 11% and 73%. In the last two analyses, the optimum pressure of 2.5 MPa minimizes the heat exchangers' areas. The results also show that the net power output generated from a limited energy source doesn't influence the results of the energy analysis. However, an increase of the net power output decreases the exergetic efficiency while at the same time it increases the heat exchangers' surface.

11/00703 Vortex excitation: three design rules tested on 13 industrial chimneys

Verboom, G. K. and van Koten, H. *Journal of Wind Engineering and Industrial Aerodynamics*, 2010, 98, (3), 145–154.

The design rules for cross-wind vibrations given by DIN 4133 and the CICIND model code can give results that differ by a factor of six or more. Still, both design rules are included in the Eurocode. In this paper the authors apply a model closely related to the Vickery–Basu model, of which the CICIND model code and several other codes of practice are simplified derivates, to 13 industrial steel chimneys of which the operational history is known in some detail. The results are much more reliable than either DIN 4133 or the CICIND model code. The dominant parameter is the influence of turbulence on the aerodynamic damping parameter. This site specific parameter is neglected or too strongly simplified in all current codes of practice.

11/00704 Wavelet enhanced visualization of solids distribution in the top of a CFB

Xiong, X. *et al. Chemical Engineering Journal*, 2010, 158, (1), 61–68.

In a circulating fluidized bed (CFB) the cross-sectional solids distribution in the top zone may differ from that in the lower zones. Particularly, the solids concentration distribution around the exit could be noticeably higher than that in other places. As an important factor affecting heat transfer in CFBs, cross-sectional solids concentration has rarely been investigated by means of online process tomographic visualization. This work uses electrical capacitance tomography (ECT) to visualize the solids distributions in the top zone of a CFB. In addition, wavelet methods are used for de-noising and image enhancement, and the effects are found in three aspects: (1) the influence of noise in the raw data can be reduced, which improves the quality of the reconstructed images; (2) the noise in the reconstructed ECT images can be reduced, providing a means for further image enhancement; (3) the rough patches of the images can be visibly smoothed, which is valuable for image refinement under coarse image pixel divisions. Experimental data revealed important features of the solids distribution, including (1) the core-annulus flow pattern, (2) the high solids concentration in the corners of the riser, (3) the moderate effect of the cap of the riser, and (4) the high solids concentration near the exit.

10 SPACE HEATING AND COOLING/HEAT PUMPS

11/00705 A technique for uncertainty analysis for inverse heat conduction problems

Blackwell, B. and Beck, J. V. *International Journal of Heat and Mass Transfer*, 2010, 53, (4), 753–759.

A technique is presented for the uncertainty analysis of the linear inverse heat conduction problem (IHCP) of estimating heat flux from interior temperature measurements. The selected IHCP algorithm is described. The uncertainty in thermal properties and temperature measurements is considered. A propagation of variance equation is used for the uncertainty analysis. An example calculation is presented. Parameter importance factors are defined and computed for the example problem; the volumetric heat capacity is the dominant parameter and an explanation is offered. Thoughts are presented on extending the analysis to include the non-linear problem of temperature-dependent properties.

11/00706 Accurate heat capacity data at phase transitions from relaxation calorimetry

Suzuki, H. *et al. Cryogenics*, 2010, 50, (10), 693–699.

Extracting accurate heat capacities by conventional relaxation calorimetry at first-order or very sharp second-order phase transitions is extremely difficult. The so-called 'scanning method' provides a key to overcome this challenge. Here, new corrections are introduced into the data analysis of this method. Critical examinations of the improvements are made experimentally by investigating the well-studied first-order ferroelectric phase transitions of KH_2PO_4 and $BaTiO_3$ using a commercial relaxation calorimeter physical property measurement system (PPMS) supplied by Quantum Design. The results for KH_2PO_4 are shown to be excellent; a very sharp peak in heat capacity is obtained and the absolute values are shown to agree well with the previous results obtained by adiabatic calorimetry on much larger samples. The critical behaviour of the heat capacity in the vicinity of the transition temperature, as well as the thermodynamic quantities such as the transition enthalpy and entropy, also agrees very well with the previous results. For $BaTiO_3$, clear hysteretic behaviour of the transition is observed for heating and cooling curves.

11/00707 Characteristics of two-phase flow pattern transitions and pressure drop of five refrigerants in horizontal circular small tubes

Pamitran, A. S. *et al. International Journal of Refrigeration*, 2010, 33, (3), 578–588.

An experimental investigation on the characteristics of two-phase flow pattern transitions and pressure drop of R-22, R-134a, R-410A, R-290 and R-744 in horizontal small stainless steel tubes of 0.5, 1.5 and 3.0 mm inner diameters is presented. Experimental data were obtained over a heat flux range of 5–40 kW/m^2, mass flux range of 50–600 kg/(m^2 s), saturation temperature range of 0–15 °C, and quality up to 1.0. Experimental data were evaluated with Wang et al. and Wojtan et al. [Wang, C.C., Chiang, C.S., Lu, D.C., 1997. Visual observation of two-phase flow pattern of R-22, R-134a, and R-407C in a 6.5-mm smooth tube. Exp. Therm. Fluid Sci. 15, 395–405; Wojtan, L., Ursenbacher, T., Thome, J.R., 2005. Investigation of flow boiling in horizontal tubes: part I – a new diabatic two-phase flow pattern map. Int. J. Heat Mass Transfer 48, 2955–2969.] flow pattern maps. The effects of mass flux, heat flux, saturation temperature and inner tube diameter on the pressure drop of the working refrigerants are reported. The experimental pressure drop was compared with the predictions from some existing correlations. A new two-phase pressure drop model that is based on a superposition model for two-phase flow boiling of refrigerants in small tubes is presented.

11/00708 Combined effects of the filling ratio and the vapour space thickness on the performance of a flat plate heat pipe

Lips, S. *et al. International Journal of Heat and Mass Transfer*, 2010, 53, (4), 694–702.

An experimental study of a flat plate heat pipe (FPHP) is presented. Temperature fields in the FPHP are measured for different filling ratios, heat fluxes and vapour space thicknesses. The system is hermetically sealed with a transparent plate for meniscus curvature radius observations by confocal microscopy. Experimental results show that the liquid distribution in the FPHP – and thus its thermal performance – depends strongly on both the filling ratio and the vapour space thickness. A small vapour space thickness induces liquid retention and thus reduces the thermal resistance of the system. Nevertheless, the vapour space thickness influences the level of the meniscus curvature radii in the grooves and hence reduces the maximum capillary pressure. As a result, it has to be carefully optimized to improve the performance of the FPHP. In all the cases, the optimum filling is in the range one to two times the total volume of the grooves. A theoretical approach, in non-working conditions, has been developed to model the distribution of the liquid inside the FPHP in function of the filling ratio and the vapour space thickness.

11/00709 Compact heat exchangers modeling: condensation

García-Cascales, J. R. *et al. International Journal of Refrigeration*, 2010, 33, (1), 135–147.

A model for the analysis of compact heat exchangers working as either evaporators or condensers is presented. This paper will focus exclusively on condensation modelling. The model is based on cell discretization of the heat exchanger in such a way that cells are analysed following the path imposed by the refrigerant flowing through the tubes. It has been implemented in a robust code developed for assisting with the design of compact heat exchangers and refrigeration systems. These heat exchangers consist of serpentine fins that are brazed to multi-port tubes with internal microchannels. This paper also investigates a number of correlations used for the calculation of the refrigerant side heat transfer coefficient. They are evaluated comparing the predicted data with the experimental data. The working fluids used in the experiments are R134a and R410A, and the secondary fluid is air. The experimental facility is briefly described and some conclusions are finally drawn.

11/00710 Comparison of heat pump performance using fin-and-tube and microchannel heat exchangers under frost conditions

Shao, L.-L. *et al. Applied Energy*, 2010, 87, (4), 1187–1197.

Vapour compression heat pumps are drawing more attention in energy saving applications. Microchannel heat exchangers can provide higher performance via less core volume and reduce system refrigerant charge, but little is known about their performance in heat pump systems under frosting conditions. In this study, the system performance of a commercial heat pump using microchannel heat exchangers as evaporator is compared with that using conventional finned-tube heat exchangers numerically and experimentally. The microchannel and finned-tube heat pump system models used for comparison of the microchannel and finned-tube evaporator performance under frosting conditions were developed, considering the effect of maldistribution on both refrigerant and air sides. The quasi-steady-state modelling results are in reasonable agreement with the test data under frost conditions. The refrigerant-side maldistribution is found remarkable impact on the microchannel heat pump system performance under the frost conditions. Parametric study on the fan speed and the fin density under frost conditions are conducted as well to figure out the best trade-off in the design of frost tolerant evaporators.

11/00711 Conduction-corrected modified effective temperature as the indices of combined and separate effect of environmental factors on sensational temperature

Kurazumi, Y. *et al. Energy and Buildings*, 2010, 42, (4), 441–448.

In living spaces, people sit or lie on the floor and adopt a posture in which much of the surface of the body is in contact with the floor. When the temperature of the spatial structure or the surface temperature of an object in contact with the human body is not equivalent to the air temperature, these effects are non-negligible. Most research examining the physiological and psychological responses of the human body has involved subjects sitting in chairs. Research that takes into account body heat balance and assessments of thermal conduction into the environment is uncommon. Thus, in this study, conduction-corrected modified effective temperature, which is a new thermal environmental index incorporating heat conduction, is defined in order to make possible the evaluation of thermal environments that take into account different postures. This sensational temperature index converts the effects of the following parameters into a temperature equivalent: air velocity, thermal radiation, contact material surface temperature and humidity. This index has the features of a summation formula. Through the use of these parameters, it is possible to represent and quantify their composite influence on bodily sensation and the effects of discrete meteorological elements through an evaluation on an identical axis.

11/00712 Control characteristics and heating performance analysis of automatic thermostatic valves for radiant slab heating system in residential apartments

Ahn, B.-C. and Song, Y.-C. *Energy*, 2010, 35, (4), 1615–1624.

Computer simulations and experiments are carried out to research the control characteristics and heating performances for a radiant slab heating system with automatic thermostatic valves in residential apartments. An electrical equivalent R–C circuit is applied to analyse the unsteady heat transfer in the house. In addition, the radiant heat transfer between slabs, ceilings and walls in the room is evaluated by enclosure analysis method. Results of heating performance and control characteristics were determined from control methods such as

automatic thermostatic valves, room air temperature-sensing method, water-temperature-sensing method, proportional control method, and on–off control method.

11/00713 Crosswinds effect on the performance of natural draft wet cooling towers

Al-Waked, R. *International Journal of Thermal Sciences*, 2010, 49, (1), 218–224.

Effects of crosswinds on the thermal performance of natural draft wet cooling towers (NDWCTs) have been investigated. A three-dimensional CFD model has been used to determine the effect of crosswinds on NDWCTs performance surrounded by power plant building structures. The three-dimensional CFD model has utilized the standard k–ε turbulence model as the turbulence closure. Two cases have been investigated: a stand-alone NDWCT and two NDWCTs within a proposed power plant structures (PPS). It has been found that regardless of the crosswinds direction, an increase of 1.3 k or more could be predicted at crosswinds speeds greater than 4 m/s. Furthermore, the performance of NDWCTs under crosswinds has been found to be dependent on the three major factors: the structure of the approaching crosswinds and whether it is disturbed or undisturbed, the location of the NDWCT in the wake of the other NDWCT, and the location of the NDWCT in front of/in the wake of the PPS. When comparing results from the stand-alone and from the NDWCTs within PPS simulations, differences in ΔT_{wo} were found to be less than 1 K for the whole span of crosswinds speeds and could be decreased to 0.7 K for speeds less than 8 m/s. Finally, results obtained from the simulation of a stand-alone NDWCT could be used instead of those from NDWCTs within PPS at a certain crosswinds direction for qualitative comparisons.

11/00714 Design of a compact absorber with a hydrophobic membrane contactor at the liquid–vapor interface for lithium bromide–water absorption chillers

Ali, A. H. H. *Applied Energy*, 2010, 87, (4), 1112–1121.

In this study, design of a compact plates-and-frames absorber possessing a hydrophobic microporous membrane contactor at the aqueous solution–water vapour interface is performed analytically. The absorber is a component of a 5 kW cooling capacity single-effect lithium bromide–water absorption chiller that incorporates a hot water thermally driven generator and a water-cooled absorber and condenser. Good agreement prevailed for the analytically evaluated water vapour mass transfer flux and aqueous solution outlet temperature when compared with measured values at similar operating conditions. At design point conditions, the main design parameters obtained are a membrane contactor area of 6.06 m^2, a ratio of the mass transfer area to absorber net volume ($Am/Vnet$) of 130.1(m^2/m^3), and ratio of the membrane area (mass transfer area) in this design configuration to the area required for heat transfer is 1.162, respectively. The results clearly indicate that the aqueous solution channel thickness is the most significant design parameter that affects the absorber size compactness; the thinner the thickness of the solution channel, the higher the ratio ($Am/Vnet$). The results also show the countercurrent refrigerant flow with the aqueous solution has positive effects on the absorber size compactness.

11/00715 Dynamic surface tension of heat transfer additives suitable for use in steam condensers and absorbers

Jun, Y.-D. *et al. International Journal of Refrigeration*, 2010, 33, (2), 428–434.

Additives are often effectively used in enhancing heat transfer by creating a surface tension gradient on the surface of a condensate film to induce Marangoni driven 'dropwise-like' condensation. The objective of the current study is to use the maximum bubble pressure method (MBPM) to evaluate dynamic behaviour of the surface tension of solutions of three different additives (2-ethoxy ethanol, isobutylamine, and 2-ethyl-1-hexanol) of varying concentrations with water. It was shown that the effects of 2-ethoxy ethanol on surface tension was primarily dependent on solute concentration and showed little dependence on time (i.e. surface age of bubble). While both isobutylamine and 2-ethyl-1-hexanol showed strong dependence on both concentration and time, the effects of the later were far more dramatic. The results for all solutions are presented as functions of concentration and time (i.e. surface age of bubble).

11/00716 Entropy generation minimization for charging and discharging processes in a gas-hydrate cool storage system

Bi, Y. *et al. Applied Energy*, 2010, 87, (4), 1149–1157.

Thermodynamic optimization models of gas-hydrate cool storage and cool release processes are established in this paper. The optimal temperature configuration at the sensible heat transfer stage and the optimal gas hydrate phase change rate configuration at the phase change stage in the processes of gas hydrate charging and discharging are obtained by taking entropy generation minimization as optimization objective. The optimal control strategies of the cool storage system are determined. The research results indicate that the optimal operating characteristic of the gas-hydrate cool storage system can be achieved by keeping the phase change rates uniform, which are regulated and controlled according to constant heat transfer rates in the charging and discharging processes of gas hydrate. The analysis method and the results presented in this paper can provide important guidelines for optimal design and operation of gas-hydrate cool storage system.

11/00717 Evaluation of a heat pump system for greenhouse heating

Aye, L. *et al. International Journal of Thermal Sciences*, 2010, 49, (1), 202–208.

Greenhouse heating costs for some commercial growers in southern Australia are now a significant production cost. This is particularly the case for those operators who installed heating systems using liquefied petroleum gas (LPG) when this fuel was relatively inexpensive. Heat pump systems used in various configurations have been suggested as an option for reducing energy use and costs for greenhouse heating, particularly if off-peak electricity is used. This paper investigates the financial and environmental viability of an air-to-water heat pump system for a 4000 m^2 greenhouse, located 120 km north of Melbourne, Victoria. The simulation software, TRNSYS, was used to predict the performance of the system. The heat pump system was found to have a simple payback period of approximately 6 years and reduce LPG consumption by 16%. Greenhouse gas emissions were 3% higher using the heat pump system, compared to the existing LPG boiler.

11/00718 Experimental investigation of header configuration on two-phase flow distribution in plate-fin heat exchanger

Wang, S. *et al. International Communications in Heat and Mass Transfer*, 2010, 37, (2), 116–120.

The two-phase flow distribution in a plate-fin heat exchanger has been experimentally studied under different operation conditions. The results indicate that two-phase flow distribution is more complex and non-uniform than that of single-phase flow. The distribution uniformity of liquid-phase deteriorates with the decrease of Re_{gas} and Re_{liq}. The distribution uniformity of gas-phase deteriorates with Re_{liq}, but improves with Re_{gas}. The improved header with perforated baffle can effectively improve the uniformity of two-phase flow distribution and dryness distribution. The values of S_{liq}, S_{gas} and S_{dry} decrease by 5.4–44.0%, 4.7–35.0% and 11.7–30.0%, respectively. The conclusion is of great significance in the optimum design of plate-fin heat exchangers.

11/00719 Experimental investigation of moderately high temperature water source heat pump with non-azeotropic refrigerant mixtures

Zhang, S. *et al. Applied Energy*, 2010, 87, (5), 1554–1561.

Experimental investigations were carried out on non-azeotropic refrigerant mixtures, named M1A (mass fraction of 20%R152a and 80%R245fa), M1B (mass fraction of 37% R152a and 63%R245fa) and M1C (mass fraction of 50%R152a and 50%R245fa), based on a water-to-water heat pump system in the condensing temperature range of 70–90 °C with a cycle temperature lift of 45 °C. Performance of R245fa was tested for comparison. Unfair factors in experimental comparative evaluation research with the same apparatus were identified and corrected. Experimental cycle performance of the mixtures were tested and compared with improved experimental assessment methodology. The results show that all of the mixtures deliver higher discharge temperature, higher heating capacity, higher COP and higher $\varepsilon_{h,c}$ than R245fa. M1B presents the most excellent cycle performance and is recommended as working fluid for moderate/high temperature heat pump.

11/00720 Experimental investigation on energy separation in a counter-flow Ranque–Hilsch vortex tube: effect of cooling a hot tube

Eiamsa-ard, S. *et al. International Communications in Heat and Mass Transfer*, 2010, 37, (2), 156–162.

This paper presents the effects of cooling of a hot tube on the temperature separation (the temperature reduction of cold air) and cooling efficiency in a counter-flow Ranque–Hilsch vortex tube (RHVT). In the experiments, the hot tube is directly cooled by cooling water jacket. The obtained results reveal that cooling water plays an important role in promoting the energy separation in the RHVT. Consequently, the temperature reduction of the cold tube (T_i–T_c) and thus cooling efficiency in the RHVT with cooling of a hot tube is found to be higher than those of the RHVT without the cooling, under the similar operating conditions. Over the range investigated, the mean cold air temperature reduction and cooling efficiency of the RHVT with the cooling of a hot tube are respectively, 5.5 to 8.8% and 4.7 to 9% higher than those of the RHVT without the cooling.

11/00721 Experimental study of using PCM in brick constructive solutions for passive cooling

Castell, A. *et al. Energy and Buildings*, 2010, 42, (4), 534–540.

This work presents the results of an experimental set-up to test phase change materials with two typical construction materials (conventional and alveolar brick) for Mediterranean construction in real conditions. Several cubicles were constructed and their thermal performance throughout the time was measured. For each construction material, macroencapsulated PCM is added in one cubicle (RT-27 and SP-25 A8). The cubicles have a domestic heat pump as a cooling system and the energy consumption is registered to determine the energy savings achieved. The free-floating experiments show that the PCM can reduce the peak temperatures up to 1 °C and smooth out the daily fluctuations. Moreover, in summer 2008 the electrical energy consumption was reduced in the PCM cubicles about 15%. These energy savings resulted in a reduction of the CO_2 emissions about 1–1.5 kg/year/m^2.

11/00722 Global optimization of a central air-conditioning system using decomposition–coordination method

Yao, Y. and Chen, J. *Energy and Buildings*, 2010, 42, (5), 570–583.

The global optimization model for the overall control of air-conditioning system aiming at the minimum energy consumption is developed in this work. The method of decomposition–coordination, which is adept at solving the ultrahigh-dimensional optimization problems, is used for the model solution. Taking one real central air-conditioning system as the case study, the hourly optimal conditions of all equipments in this system on one operation day were simulated by the global optimization model. To examine the validity of decomposition–coordination algorithm, direct-search method (which is admitted to be the most reliable in optimization calculation) is used to make the comparison. It showed that the optimal results obtained by the two methods were essentially the same, but decomposition–coordination method would have much higher calculation efficiency than direct-search method. The energy analysis indicated that the energy saving brought by the global optimization was mainly thanks to the adjustment of pumps and fans rather than that of the chillers. It was believed as well that more energy saving would be achieved under the lower load condition of the system if the globally optimal control scheme were implemented.

11/00723 Heat transport in structured packings with co-current downflow of gas and liquid

Pangarkar, K. *et al. Chemical Engineering Science*, 2010, 65, (1), 420–426.

Improvements in catalyst activity make the heat transport in fixed bed reactors increasingly important. Structured packings operated in two-phase flow are expected to outperform randomly packed beds, but heat transfer data on structured packings is scarce. In this work structured packings such as OCFS (open cross-flow structures), CCFS (closed cross-flow structures), knitted wire, and foam were characterized with respect to the heat transfer performance. A dedicated set-up was designed and built which enabled the heat transfer rates in two-phase flow at ambient pressure in the absence of reaction to be measured. Benchmarking and set-up validation was carried out using glass beads. The structured packings – especially OCFS and CCFS – show heat transfer coefficients that are superior over those of glass beads, at lower energy dissipation.

11/00724 Hexamethylene dilauroyl, dimyristoyl, and dipalmytoyl amides as phase change materials for thermal energy storage

Canik, G. and Alkan, C. *Solar Energy*, 2010, 84, (4), 666–672.

Hexamethylene dilauroyl, dimyristoyl, and dipalmytoyl amides have been produced as solid–liquid phase change materials via condensation of hexamethylene diamine with the respective acyl chlorides (lauroyl chloride, myristoyl chloride, and palmytoyl chloride) and were characterized by FT-IR, NMR, DSC, and TG analysis. Hexamethylene dilauroyl, dimyristoyl, and dipalmytoyl amides crystallized due to structural symmetry and flexibility of long alkyl groups. They were characterized by DSC and FT-IR spectroscopy before and after thermal cycling to determine their thermal reliability. Phase change enthalpies were found 110.1 and $-103.3\,J\,g^{-1}$ for hexamethylene dilauroyl amide (*N*,*N*′-hexamethylene didodecanamide), 116.9 and $-110.4\,J\,g^{-1}$ for hexamethylene dimyristoyl amide (*N*,*N*′-hexamethylene ditetradecanamide), and 144.5 and $-140.5\,J\,g^{-1}$ for hexamethylene dipalmytoyl amides (*N*,*N*′-hexamethylene dihexadecanamide) by DSC. The endurance of hexamethylene dilauroyl, dimyristoyl, and dipalmytoyl amides was studied by TG analysis.

11/00725 Hierarchical fuzzy control of low-energy building systems

Yu, Z. and Dexter, A. *Solar Energy*, 2010, 84, (4), 538–548.

A hierarchical fuzzy supervisory controller is described that is capable of optimizing the operation of a low-energy building, which uses solar energy to heat and cool its interior spaces. The highest level fuzzy rules choose the most appropriate set of lower level rules according to the weather and occupancy information; the second-level fuzzy rules determine an optimal energy profile and the overall modes of operation of the heating, ventilating and air-conditioning system; the third-level fuzzy rules select the mode of operation of specific equipment, and assign schedules to the local controllers so that the optimal energy profile can be achieved in the most efficient way. Computer simulation is used to compare the hierarchical fuzzy control scheme with a supervisory control scheme based on expert rules. The performance is evaluated by comparing the energy consumption and thermal comfort.

11/00726 Improvements of high-temperature drying heat pumps

Minea, V. *et al. International Journal of Refrigeration*, 2010, 33, (1), 180–195.

Inadequate integration and/or inappropriate operating parameters of heat pump dryers may lead to troubles as too high/low discharge/suction pressures, low dehumidification efficiency and even mechanical damage to the compressor. This paper will help fix a number of common design errors and/or omissions, and suggests original control methods to avoid undesirable operational incidents and improve overall energy performance of high-temperature drying heat pumps. The scope is to provide normal and safe operating conditions, and thus accelerate the implementation of industrial drying heat pumps.

11/00727 Modelling of the borehole filling of double U-pipe heat exchangers

Oppelt, T. *et al. Geothermics*, 2010, 39, (3), 270–276.

A new model MISOS is proposed for the simulation of the borehole filling (grout) of double U-pipe heat exchangers. When simulating ground-coupled heat pumps, a suitable model of the filling is necessary because the temperature of the filling effects the temperature of the heat carrier fluid. The filling is divided into three elements whose geometry corresponds to the different temperature zones. For each time step, the temperatures of the filling elements can be calculated from energy balances. MISOS is very fast compared to computational fluid dynamics (CFD) algorithms. CFD calculations were performed for different shank spacings, and results compared with those obtained from MISOS. If the pipe shanks are situated between the axis and the wall of the borehole, nearly the same difference of the fluid temperature between inlet and outlet is predicted by MISOS and CFD. For a minimal shank spacing, heating is overpredicted by about 6% for an extraction period of 3 h while an underprediction of about 9% is obtained for maximal shank spacing.

11/00728 Operation of superconducting magnet with dilution refrigerator insert in zero boil-off regime

Kirichek, O. *et al. Cryogenics*, 2010, 50, (10), 666–669.

The combination of high magnetic field and ultra-low temperatures has proved to be indispensable for a broad range of condensed matter physics experiments. However, problems with the global helium supply have raised significant concern about affordability of conventional cryogenic equipment. The latest developments in cryo-cooler technology offer a new generation of cryogenic systems in which the cryogen consumption can be significantly reduced and in some cases completely eliminated. The authors have demonstrated a new high magnetic field – ultra-low temperature neutron scattering sample environment system based on re-condensing technology. These tests have shown that the 9 T superconducting magnet, built for the ISIS facility, can be run with a dilution refrigerator insert in continuous zero boil-off regime without any additional cooling.

11/00729 Performance enhancement of a heat pump system with ice storage subcooler

Hsiao, M.-J. *et al. International Journal of Refrigeration*, 2010, 33, (2), 251–258.

This article experimentally investigates the thermal performance of a heat pump system with an ice storage subcooler. The system supplies heating and cooling demands to two greenhouses with temperature ranging 308–323 K and 273–291 K respectively and utilizes an ice storage tank to subcool the condensed refrigerant, which can enhance the system coefficient of performance (COP). The ice storage tank charges for storing ice, when the cooling load is less than the nominal cooling capacity. While the cooling load is larger than the nominal cooling capacity, the ice storage tank discharges for subcooling. The results show that in the charge mode the heat pump COP of ice storage system is 12% higher than that without ice storage tank. Under the discharge mode, the ice storage system provides the refrigerator COP 15% higher than that without ice storage tank.

11/00730 Performance study of spot cooling of tractor cabinet

Kabeel, A. E. *et al. Energy*, 2010, 35, (4), 1679–1687.

This study examined theoretically and experimentally the performance of spot cooling of a tractor cabinet including a single internal heat source (tested body) by using a vortex tube. In the theoretical study, the cabinet is cooled from the roof by one port while the lower and side walls temperature is kept constant. The effect of inlet and outlet air ports positions in the cabinet is considered. The influence of varying some parameters was studied, for example velocity and temperature of inlet cold air to the cabinet, the pressure of inlet air to the vortex tube and the cold fraction of the vortex tube in the presence of a heat source with a constant heat flux of 120 W/m^2. The FLUENT 6.3.26 package was used in the numerical study. The calculations were performed for a ventilation effectiveness factor (VEF) ranging from 0.58 to 1.29. The best position for the inlet locations in this study was found in upper right side of roof and the outlet locations in upper left side of cabinet. To validate the numerical model, an experimental test rig has been designed and constructed with the actual dimensions of a tractor cabinet. The experiments were carried out with the same conditions as the ideal case. The comparison of the experimental data, for that of best position of the inlet port, with the theoretical results gives a satisfactory agreement.

11/00731 Preparation, characterization and thermal properties of PMMA/*n*-heptadecane microcapsules as novel solid–liquid microPCM for thermal energy storage

Sari, A. *et al. Applied Energy*, 2010, 87, (5), 1529–1534.

This study is focused on the preparation, characterization and thermal properties of microencapsulated *n*-heptadecane with polymethylmethacrylate shell. The PMMA/heptadecane microcapsules were synthesized as novel solid–liquid microencapsulated phase change material (microPCMs) by emulsion polymerization method. The chemical and thermal characterization of the microPCMs were investigated using scanning electron microscopy (SEM), differential scanning calorimetry (DSC) and thermogravimetry analysis (TGA). The diameters of microPCMs were found in the narrow range (0.14–0.40 μm) under the stirring speed of 2000 rpm. The spherical surfaces of microPCMs were smooth and compact. The DSC results show that microPCMs have good energy storage capacity. Thermal cycling test showed that the microPCMs have good thermal reliability with respect to the changes in their thermal properties after repeated 5000 thermal cycling. TGA analyses also indicated that the microPCMs degraded in three steps and have good thermal stability. Based on all results, it can be considered that the PMMA/heptadecane microcapsules as novel solid–liquid microPCMs have good energy storage potential.

11/00732 Shell side CFD analysis of a small shell-and-tube heat exchanger

Ozden, E. and Tari, I. *Energy Conversion and Management*, 2010, 51, (5), 1004–1014.

The shell side design of a shell-and-tube heat exchanger; in particular the baffle spacing, baffle cut and shell diameter dependencies of the heat transfer coefficient and the pressure drop are investigated by numerically modelling a small heat exchanger. The flow and temperature fields inside the shell are resolved using a commercial CFD package. A set of CFD simulations is performed for a single shell and single tube pass heat exchanger with a variable number of baffles and turbulent flow. The results are observed to be sensitive to the turbulence model selection. The best turbulence model among the ones considered is determined by comparing the CFD results of heat transfer coefficient, outlet temperature and pressure drop with the Bell–Delaware method results. For two baffle cut values, the effect of the baffle spacing to shell diameter ratio on the heat exchanger performance is investigated by varying flow rate.

11/00733 The Impact of thermostatic expansion valve heating on the performance of air-source heat pumps in heating mode

Gao, Z. *Energy Conversion and Management*, 2010, 51, (4), 732–739.

This paper discusses the strategy of improving the efficiency of air-source heat pumps by adding a small amount of heat to the sensor of the thermostatic expansion valve (TXV). TXV heating retards the closing of the valve and boosts energy efficiency in heating mode. Test results demonstrate that appropriate TXV heating achieves an improvement in coefficient of performance (COP) and thermal comfort. The required heating power is no more than 40 W and the additional equipment cost is less than $20 at manufacturer cost (2006). Thus, the strategy of TXV heating is both technologically practical and low cost.

11/00734 The surface tension effects in boiling heat transfer of cryogenic LN_2 on an ellipsoid

Hu, H.-P. *Nuclear Engineering and Design*, 2010, 240, (1), 139–145.

The study researched into a simple theoretical model for turbulent film boiling heat transfer on an ellipsoid with influence of surface tension. It begins from assuming an isothermal ellipsoid immersed in the stagnant saturated liquid. The effects of non-linear thermal conductivity, absolute viscosity, and the eddy diffusivity in the vapour film are all included in this paper. The results show, for higher eccentricity values, the eccentricity and the surface tension have some slight influence on the mean Nusselt. However, for lower eccentricity values, the influence of eccentricity and surface tension effects on the mean Nusselt can almost be neglected. Finally, a comparison between the results of the present study and those reported in previous theoretical and experimental studies is provided. And the results were found in a good agreement with the previous data.

11/00735 Thermodynamic analysis and parametric study of a closed Brayton cycle thermal management system for scramjet

Qin, J. *et al. International Journal of Hydrogen Energy*, 2010, 35, (1), 356–364.

A closed Brayton cycle thermal management system is proposed for a regeneratively cooled scramjet to reduce the hydrogen fuel flow for cooling, through converting part of the heat from fuel to other forms of energy to decrease the heat that must be taken away by hydrogen fuel. Fuel heat sink (cooling capacity) is thus indirectly increased. Instead of carrying excess fuel for cooling or seeking for any new coolant, the fuel flow for cooling is reduced, and fuel onboard is adequate to satisfy the cooling requirement for the whole hypersonic vehicle. A parametric study of an irreversible closed Brayton cycle thermal management system for scramjet has been performed with external as well as internal irreversibilities. It is known through performance analyses that closed Brayton cycle thermal management system has excellent potential performance over conventional regenerative cooling, due to the reduction in fuel flow for cooling and additional power output.

11/00736 Towards maximal heat transfer rate densities for small-scale high effectiveness parallel-plate heat exchangers

Rogiers, F. and Baelmans, M. *International Journal of Heat and Mass Transfer*, 2010, 53, (4), 605–614.

This paper addresses the question to what extent parallel-plate heat exchangers can be downsized without loss of thermal-hydraulic performance. It is shown that when the characteristic length scales of the channels are reduced at a constant pressure drop, the effectiveness exhibits a maximum due to axial heat conduction. The point of maximal effectiveness is found to correspond to a maximal thermal power density and thus to the minimal volume required for obtaining that effectiveness. Based on asymptotic relations for the effectiveness in the small and large channel limit, closed-form expressions are derived for the optimum geometric parameters that maximize power density in the limit of design effectiveness approaching unity. These relations are extended to a broader effectiveness range by means of dimensionless correction functions that are calculated numerically. The resulting expressions define optimal elemental units that can be used to construct parallel-plate counter-flow heat exchangers with the lowest possible core volume for effectiveness values between 0.53 and 1.

11/00737 Unsteady natural convection cooling of a water storage tank with an internal gas flue

Hmouda, I. *et al. International Journal of Thermal Sciences*, 2010, 49, (1), 36–47.

The cooling process by natural convection in cylindrical cavities is a phenomenon which takes place in several applications such as solar energy systems. In the present work a storage tank with an internal gas flue is studied experimentally and numerically during its long-term cooling process. The computational domain includes two fluids, i.e. water in the store and air in the chimney, and two external and internal layers of steel separated by polyurethane insulation material. In this paper, the numerical and the experimental analysis of the temperature field inside the tank submitted to an external convection cooling process with a constant convection heat transfer coefficient is presented. The air and the water temperature profiles along the vertical lines are obtained experimentally and numerically, for a cooling period of 90 h. The numerical analysis is carried out using a specific CFD code developed for the present work; an axisymmetric domain has been considered. Finally, a detailed description of the phenomena that occur inside the water part of the domain during the cooling process is also provided.

11 ENGINES

Power generation and propulsion, electrical vehicles

11/00738 A highly efficient six-stroke internal combustion engine cycle with water injection for in-cylinder exhaust heat recovery

Conklin, J. C. and Szybist, J. P. *Energy*, 2010, 35, (4), 1658–1664.

A concept adding two strokes to the Otto or diesel engine cycle to increase fuel efficiency is presented here. It can be thought of as a four-stroke Otto or diesel cycle followed by a two-stroke heat recovery steam cycle. A partial exhaust event coupled with water injection adds an additional power stroke. Waste heat from two sources is effectively converted into usable work: engine coolant and exhaust gas. An ideal thermodynamics model of the exhaust gas compression, water injection and expansion was used to investigate this modification. By changing the exhaust valve closing timing during the exhaust stroke, the optimum amount of exhaust can be recompressed, maximizing the net mean effective pressure of the steam expansion stroke (MEP_{steam}). The valve closing timing for maximum MEP_{steam} is limited by either 1 bar or the dew point temperature of the expansion gas/moisture mixture when the exhaust valve opens. The range of MEP_{steam} calculated for the geometry of a conventional gasoline engine and is from 0.75 to 2.5 bars. Typical combustion mean effective pressures ($MEP_{combustion}$) of naturally aspirated gasoline engines are up to 10 bar, thus this concept has the potential to significantly increase the engine efficiency and fuel economy.

11/00739 Computational thermodynamic analysis of compression ignition engine

Sakhrieh, A. *et al. International Communications in Heat and Mass Transfer*, 2010, 37, (3), 299–303.

This paper presents diesel engine simulation taking into consideration heat transfer and variable specific heats. A dual Weibe function is used to model the heat release. It was found that early injection timing leads to higher levels of pressure and temperature in the cylinder. Also, it was found that BMEP is more sensitive to equivalence ratio than to engine speed. Higher values of equivalence ratio lead to lower thermal efficiency even an increase in the value of BMEP was revealed. For medium engine speeds between 2000 and 3000, it was found that the optimum equivalence ratio is between 0.5 and 0.7. However, for low engine speeds the optimum equivalence ratio was around 0.35. For high engine speeds the thermal efficiency was almost independent of equivalence ratios higher than 0.4.

11/00740 Cooling of a permanent magnet electric motor with a centrifugal impeller

Li, H. *International Journal of Heat and Mass Transfer*, 2010, 53, (4), 797–810.

This paper presents a thermal fluid analysis on the air cooling of a permanent magnet electric motor with a centrifugal impeller. A numerical model is developed for the heat transfer and fluid flow process. The flow rates of the cooling air are also experimentally measured. The agreement between the numerical model prediction and experimental data is reasonably good. Detailed structures of the cooling flow are presented. Convection heat transfer on the surface of the armature is quantified. Comments on the application of the motor architecture are given. Design modifications are proposed for performance improvements.

11/00741 Evaluation of thermal efficiency and energy conversion of thermoacoustic Stirling engines

Hu, Z. H. *et al. Energy Conversion and Management*, 2010, 51, (4), 802–812.

Thermodynamic cycle transferring heat and work was executed in thermoacoustic engines, when the acoustic resonators substituted the moving mechanical components of the traditional heat engines. Based on the traveling-wave phasing and reversible heat transfer, thermo-acoustic Stirling engines could achieve 70% of the Carnot efficiency theoretically, if the inevitable viscous dissipation in resonators was also counted as exported power. It should be pointed out an error on this efficiency evaluation in the previous literatures. More than 70% of the acoustic power production was often consumed by the side-branch resonator that was the essential configuration to build up a thermo-acoustic Stirling engine. According to the simulation results and some experimental data, the actual available acoustic power consumed by the acoustic loads was restricted by the operating peak-to-mean pressure ratio, i.e. $|p_1/p_m|$. When the peak-to-mean pressure ratio operated on 4–6.5%, the thermal efficiency and power density of the available acoustic power reached higher levels. But the available acoustic power would approach zero when $|p_1/p_m|$ attained 10%. It was approved that the turbulence oscillation occurred on the higher $|p_1/p_m|$ (usually $>4\%$) was the main reason of the excess dissipation in the side-branch resonator. This character of the available power limited the wide application of thermoacoustic Stirling engines. The evaluation of thermal efficiency and energy conversion also indicated the improving direction of thermoacoustic Stirling engines. Generators driven by the thermoacoustic Stirling engines were an effective way, due to the elimination of the side-branch resonator. To achieve a high power density and a high pressure ratio on the higher available power efficiency level, the standing-wave thermoacoustic engines might outvie the travelling-wave thermoacoustic engines. To enjoy the best features of standing-wave engines and traveling-wave engines simultaneously, exploiting multi-stage thermoacoustic engines, such as cascade engines, etc., would be an important research direction.

11/00742 High-speed chemical species tomography in a multi-cylinder automotive engine

Wright, P. *et al. Chemical Engineering Journal*, 2010, 158, (1), 2–10.

The application of chemical species tomography (CST) in a multi-cylinder automotive engine is discussed. This technique offers high-speed continuous imaging of hydrocarbon fuel distribution and mixing within the combustion chamber and is therefore of interest to both engine designers and combustion scientists. Many of the methods described are equally applicable to chemically selective imaging of other highly dynamic mixing and reaction processes. A measurement grid consisting of 27 dual-wavelength optical paths has been implemented in one cylinder of an otherwise standard four-cylinder port-injected gasoline engine, using a unique optical access layer (OPAL) carrying embedded optical fibres and collimators. The OPAL provided adequate performance on many beams for more than 2 h of fired engine operation. To improve sensitivity and to cope with fuel spray injection directly into the cylinder (in other engine types), a low-noise opto-electronic system has been developed, offering laser intensity modulation at frequencies up to 1 MHz. Dual-wavelength measurements are recorded on each channel at 100 kSPS, prior to off-line processing that typically reduces the effective frame rate to 3000–4000 frames/s, dependent on engine speed. The performance of the system was assessed, using running conditions chosen to provide a qualitatively known (homogeneous) fuel distribution for validation purposes. Examples of measured data and processing schemes are discussed. Sample tomographic images, obtained using a novel quality-based approach to data selection, are presented.

11/00743 Influence of fuel type, dilution and equivalence ratio on the emission reduction from the auto-ignition in an homogeneous charge compression ignition engine

Machrafi, H. *et al. Energy*, 2010, 35, (4), 1829–1838.

One technology that seems to be promising for automobile pollution reduction is the homogeneous charge compression ignition (HCCI). This technology still faces auto-ignition and emission-control problems. This paper focuses on the emission problem, since it is incumbent to realize engines that pollute less. For this purpose, this paper presents results concerning the measurement of the emissions of CO, NO_x, CO_2, O_2 and hydrocarbons. HCCI conditions are used, with equivalence ratios between 0.26 and 0.54, inlet temperatures of 70 °C and 120 °C and compression ratios of 10.2 and 13.5, with different fuel types: gasoline, gasoline surrogate, diesel, diesel surrogate and mixtures of *n*-heptane/toluene. The effect of dilution is considered for gasoline, while the effect of the equivalence ratio is considered for all the fuels. No significant amount of NO_x has been measured. It appeared that the CO, O_2 and hydrocarbon emissions were reduced by decreasing the toluene content of the fuel and by decreasing the dilution. The opposite holds for CO_2. The reduction of the hydrocarbon emission appears to compete with the reduction of the CO_2 emission. Diesel seemed to produce less CO and hydrocarbons than gasoline when auto-ignited. An example of emission reduction control is presented in this paper.

11/00744 Performance and durability of a generator set CI engine using synthetic and petroleum based fuels for military applications

Wadumesthrige, K. *et al. Applied Energy*, 2010, 87, (5), 1581–1590.

The long-term performance and durability evaluation of a compression ignition (CI) engine of a diesel power generator using ultra-low sulfur diesel (ULSD) and synthetic paraffinic kerosene, (S-8) fuels have been investigated under military specifications. The brake specific fuel consumptions (BSFC) were 0.308 ± 0.013 and 0.267 ± 0.019 kg/kW-h for ULSD and S-8, respectively. The corresponding brake thermal efficiencies (BTE) were 0.287 ± 0.002 and 0.309 ± 0.005. Degradation of engine performance or engine part wear was not observed during these test periods. Analysis of lubricating oil suggests negligible engine part wear. The frequency and power output of the generator, however, were not as stable with S-8 as those with ULSD. These power and

frequency instabilities can be attributed to higher volatility and lower density and viscosity of S-8, all of which affect the fuel injection characteristics.

11/00745 Predictive piston motion control in a free-piston internal combustion engine

Mikalsen, R. *et al. Applied Energy*, 2010, 87, (5), 1722–1728.

A piston motion controller for a free-piston internal combustion engine is presented. To improve dynamic performance in the control of the piston motion and engine compression ratio, the controller response is determined from a prediction of engine top dead centre error rather than the measured value from the previous cycle. The proposed control approach showed superior performance compared with that of standard PI feedback control known from the literature due to a reduced control action time delay. The manipulation of fuel injection timing to reduce in-cylinder pressure peaks and cycle-to-cycle variations was also studied, indicating that with the piston motion estimation, the injection timing is a powerful control variable for this purpose.

11/00746 Study of diesel engine performance and emissions during a transient cycle applying an engine mapping-based methodology

Giakoumis, E. G. and Alafouzos, A. I. *Applied Energy*, 2010, 87, (4), 1358–1365.

An engine mapping-based methodology was developed in order to be able to make a first approximation of the engine performance and emissions during a speed/torque vs time transient cycle. The procedure is based on a previous steady-state experimental investigation of the engine for the formulation of polynomial expressions of all interesting engine properties with respect to engine speed and torque. Correction coefficients are then applied to account for transient discrepancies based on individual transient experiments. The developed algorithm was applied for the case of a heavy-duty diesel engine running on the European Transient Cycle. A comparative analysis was performed for each section of the cycle, which revealed that the first part (urban driving) is responsible for the biggest amount of emissions (in g) owing to the most frequent and abrupt load changes involved. The obvious advantage of the proposed methodology is the fact that the effect of internal or external (after-treatment) measures can be easily incorporated in the code and quantified in terms of emissions improvement.

11/00747 The control of a free-piston engine generator. Part 1: fundamental analyses

Mikalsen, R. and Roskilly, A. P. *Applied Energy*, 2010, 87, (4), 1273–1280.

Free-piston engines are under investigation by a number of research groups due to potential fuel efficiency and exhaust emissions advantages over conventional technology. The main challenge with such engines is the control of the piston motion, and this has not yet been fully resolved for all types of free-piston engines. This paper discusses the basic features of a single piston free-piston engine generator under development at Newcastle University and investigates engine control issues using a full-cycle simulation model. Control variables and disturbances are identified, and a control strategy is proposed. It is found that the control of the free-piston engine is a challenge, but that the proposed control strategy is feasible. Engine speed control does, however, represent a challenge in the current design.

11/00748 The control of a free-piston engine generator. Part 2: engine dynamics and piston motion control

Mikalsen, R. and Roskilly, A. P. *Applied Energy*, 2010, 87, (4), 1281–1287.

Free-piston engines are under investigation by a number of research groups due to potential fuel efficiency and exhaust emissions advantages over conventional technology. The main challenge with such engines is the control of the piston motion, and this has not yet been fully resolved for all types of free-piston engines. This paper builds on the fundamental investigations presented in the accompanying paper and investigates the dynamics of the engine and the feasibility of classical control approaches. The response of the engine to rapid load changes are investigated using decentralized PID, PDF and disturbance feedforward. It is found that the engine is sensitive to rapid load changes but that in constant power applications standard control techniques provide satisfactory performance. The influence of cycle-to-cycle variations in the combustion process are investigated, but not found to be critical for engine operation.

11/00749 Time- and space-resolved quantitative LIF measurements of formaldehyde in a heavy-duty diesel engine

Donkerbroek, A. J. *et al. Combustion and Flame*, 2010, 157, (1), 155–166.

Formaldehyde (CH_2O) is a characteristic species for the ignition phase of diesel-like fuels. As such, the spatio-temporal distribution of formaldehyde is an informative parameter in the study of the ignition event in internal combustion engines, especially for new combustion modes like homogeneous charge compression ignition (HCCI). This paper presents quantitative data on the CH_2O distribution around diesel and *n*-heptane fuel sprays in the combustion chamber of a commercial heavy-duty diesel engine. Excitation of the 4^1_0 band (355 nm) as well as the $4^1_0 2^1_0$ band (339 nm) is applied. Quantitative, spectrally resolved laser-induced fluorescence was used, calibrated by means of formalin seeding, to distinguish the contribution from CH_2O to the signal from those of other species formed early in the combustion. Typically, between 40% and 100% of the fluorescence in the wavelength range considered characteristic for formaldehyde is in fact due to other species, but the latter are also related to the early combustion. Numerical simulation of a homogeneous reactor of *n*-heptane and air yields concentrations that are in reasonable agreement with the measurements. Formaldehyde starts to be formed at about 2° of the crank angle before the rise in main heat release. There appears to be a rather localized CH_2O formation zone relatively close to the injector, out of which formaldehyde is transported downstream by the fuel jet. Once the hot combustion sets in, formaldehyde quickly disappears.

Hybrid engine systems

11/00750 CNG-diesel engine performance and exhaust emission analysis with the aid of artificial neural network

Yusaf, T. F. *et al. Applied Energy*, 2010, 87, (5), 1661–1669.

This study investigates the use of artificial neural network (ANN) modelling to predict brake power, torque, break specific fuel consumption (BSFC), and exhaust emissions of a diesel engine modified to operate with a combination of both compressed natural gas (CNG) and diesel fuels. A single cylinder, four-stroke diesel engine was modified for the present work and was operated at different engine loads and speeds. The experimental results reveal that the mixtures of CNG and diesel fuel provided better engine performance and improved the emission characteristics compared with the pure diesel fuel. For the ANN modelling, the standard back-propagation algorithm was found to be the optimum choice for training the model. A multi-layer perception network was used for non-linear mapping between the input and output parameters. It was found that the ANN model is able to predict the engine performance and exhaust emissions with a correlation coefficient of 0.9884, 0.9838, 0.95707, and 0.9934 for the engine torque, BSFC, NO_x and exhaust temperature, respectively.

11/00751 Combustion and emissions performance of a hybrid hydrogen–gasoline engine at idle and lean conditions

Ji, C. and Wang, S. *International Journal of Hydrogen Energy*, 2010, 35, (1), 346–355.

Due to the narrow flammability of gasoline, pure gasoline-fuelled spark-ignited (SI) engines always encounter partial burning or even misfire at lean conditions. Gasoline engines tend to suffer poor combustion and expel large emissions at idle conditions because of the high variation in the intake charge and low combustion temperature. Comparatively, hybrid hydrogen engines (HHE) fuelled with the mixtures of hydrocarbon fuels and hydrogen seem to achieve lower emissions and gain higher thermal efficiencies than the original hydrocarbon-fuelled engines due to the wide flammability and high flame speed of hydrogen. Since a HHE only requires a small amount of hydrogen, it also removes concerns about the high production and storage costs of hydrogen. This paper introduced an experiment conducted on a four-cylinder SI gasoline engine equipped with a hydrogen port-injection system to explore the performance of a hybrid hydrogen–gasoline engine (HHGE) at idle and lean conditions. The injection timings and durations of hydrogen and gasoline were governed by a hybrid electronic control unit (HECU) developed by the authors, which can be adjusted freely according to the commands from a calibration computer. During the test, hydrogen flow rate was varied to ensure that hydrogen volume fraction in the intake was constantly kept at 3%. For the specified hydrogen addition level, gasoline flow rate was reduced to make the engine operate at idle and lean conditions with various excess air ratios. The test results demonstrated that cyclic variations in engine idle speed and indicated mean effective pressure were eased with hydrogen enrichment. The indicated thermal efficiency was obviously higher for the HHGE than that for the original gasoline engine at idle and lean conditions. The indicated thermal efficiency at an excess air ratio of 1.37 was increased from 13.81% for the original gasoline engine to 20.20% for the HHGE with a 3% hydrogen blending level. Flame development and propagation periods were also evidently shortened after hydrogen blending.

Moreover, HC, CO and NO_x emissions were all improved after hydrogen enrichment at idle and lean conditions. Therefore, the HHE methodology is an effective and promising way for improving engine idle performance at lean conditions.

11/00752 Emission characteristics of high speed, dual fuel, compression ignition engine operating in a wide range of natural gas/diesel fuel proportions

Papagiannakis, R. G. *et al. Fuel*, 2010, 89, (7), 1397–1406.

In the effort to reduce pollutant emissions from diesel engines various solutions have been proposed, one of which is the use of natural gas as supplement to liquid diesel fuel, with these engines referred to as fumigated, dual fuel, compression ignition engines. One of the main purposes of using natural gas in dual fuel (liquid and gaseous one) combustion systems is to reduce particulate emissions and nitrogen oxides. Natural gas is a clean burning fuel; it possesses a relatively high auto-ignition temperature, which is a serious advantage over other gaseous fuels since then the compression ratio of most conventional direct injection (DI) diesel engines can be maintained high. In the present work, an experimental investigation has been conducted to examine the effects of the total air–fuel ratio on the efficiency and pollutant emissions of a high speed, compression ignition engine located at the authors' laboratory, where liquid diesel fuel is partially substituted by natural gas in various proportions, with the natural gas fumigated into the intake air. The experimental results disclose the effect of these parameters on brake thermal efficiency, exhaust gas temperature, nitric oxide, carbon monoxide, unburned hydrocarbons and soot emissions, with the beneficial effect of the presence of natural gas being revealed. Given that the experimental measurements cover a wide range of liquid diesel supplementary ratios without any appearance of knocking phenomena, the belief is strengthened that the findings of the present work can be very valuable if opted to apply this technology on existing DI diesel engines.

11/00753 Optical investigation of the combustion behaviour inside the engine operating in HCCI mode and using alternative diesel fuel

Mancaruso, E. and Vaglieco, B. M. *Experimental Thermal and Fluid Science*, 2010, 34, (3), 346–351.

In order to understand the effect of both the new homogeneous charge compression ignition (HCCI) combustion process and the use of biofuel, optical measurements were carried out into a transparent CR diesel engine. Rape seed methyl ester (RME) was used and tests with several injection pressures were performed. OH and HCO radicals were detected and their evolutions were analysed during the whole combustion. Moreover, soot concentration was measured by means of the two-colour pyrometry method. The reduction of particulate emissions with biodiesel as compared to the diesel fuel was noted. Moreover, this effect resulted higher increasing the injection pressure. In the case of RME the oxidation of soot depends mainly from O_2 content of fuel and OH is responsible of the NO formation in the chamber as it was observed for NO_x exhaust emission. Moreover, it was investigated the evolution of HCO and CO into the cylinder. HCO was detected at the start of combustion. During the combustion, HCO oxidizes due to the increasing temperature and it produces CO. Both fuels have similar trend, the highest concentrations are detected for low injection pressure. This effect is more evident for the RME fuel.

11/00754 Performance analysis and parametric optimum criteria of a class of irreversible fuel cell/heat engine hybrid systems

Zhang, X. and Chen, J. *International Journal of Hydrogen Energy*, 2010, 35, (1), 284–293.

Based on the current models of solid oxide fuel cells and two-heat-source heat engines consisting of two isothermal and two polytropic processes, a general model of a class of fuel cell/heat engine hybrid systems is established, in which multi-irreversibilities existing in real hybrid systems are taken into account. Expressions for the efficiency and power output of the hybrid systems are analytically derived from the model. The curves of the efficiency and power output of the hybrid systems varying with the current density and the efficiency versus power output curves are represented through numerical calculation. The general performance characteristics of the hybrid systems are revealed and the optimum criteria of the main performance parameters are determined. The effects of some key irreversibilities existing in the fuel cell, regenerator and two-heat-source heat engine on the performance of the hybrid systems are discussed in detail. The results obtained here are very general and may be directly used to derive the various interesting conclusions of the hybrid systems which are operated under different special cases.

11/00755 Performance and combustion characteristics of biodiesel–diesel–methanol blend fuelled engine

Qi, D. H. *et al. Applied Energy*, 2010, 87, (5), 1679–1686.

An experimental investigation was conducted to evaluate the effects of using methanol as additive to biodiesel–diesel blends on the engine performance, emissions and combustion characteristics of a direct injection diesel engine under variable operating conditions. BD50 (50% biodiesel and 50% diesel in vol.) was prepared as the baseline fuel. Methanol was added to BD50 as an additive by volume percent of 5% and 10% (denoted as BDM5 and BDM10). The results indicate that the combustion starts later for BDM5 and BDM10 than for BD50 at low engine load, but is almost identical at high engine load. At low engine load of 1500 r/min, BDM5 and BDM10 show the similar peak cylinder pressure and peak of pressure rise rate to BD50, and higher peak of heat release rate than that of BD50. At low engine load of 1800 r/min, the peak cylinder pressure and the peak of pressure rise rate of BDM5 and BDM10 are lower than those of BD50, and the peak of heat release rate is similar to that of BD50. The crank angles at which the peak values occur are later for BDM5 and BDM10 than for BD50. At high engine load, the peak cylinder pressure, the peak of pressure rise rate and peak of heat release rate of BDM5 and BDM10 are higher than those of BD50, and the crank angle of peak values for all tested fuels are almost same. The power and torque outputs of BDM5 and BDM10 are slightly lower than those of BD50. BDM5 and BDM10 show dramatic reduction of smoke emissions. CO emissions are slightly lower, and NO_x and HC emissions are almost similar to those of BD50 at speed characteristic of full engine load.

11/00756 Performance and emission characteristics of a Kirloskar HA394 diesel engine operated on fish oil methyl esters

Godiganur, S. *et al. Renewable Energy*, 2010, 35, (2), 355–359.

The high viscosity of fish oil leads to problem in pumping and spray characteristics. The inefficient mixing of fish oil with air leads to incomplete combustion. The best way to use fish oil as fuel in compression ignition (CI) engines is to convert it into biodiesel. It can be used in CI engines with very little or no engine modifications. This is because it has properties similar to mineral diesel. Combustion tests for methyl ester of fish oil and its blends with diesel fuel were performed in a kirloskar H394 DI diesel engine, to evaluate fish biodiesel as an alternative fuel for diesel engine, at constant speed of 1500 rpm under variable load conditions. The tests showed no major deviations in diesel engine's combustion as well as no significant changes in the engine performance and reduction of main noxious emissions with the exception on NO_x. Overall fish biodiesel showed good combustion properties and environmental benefits.

Transport battery development

11/00757 Optimization of MoO_3 nanoparticles as negative-electrode material in high-energy lithium ion batteries

Riley, L. A. *et al. Journal of Power Sources*, 2010, 195, (2), 588–592.

Highly uniform MoO_3 nanoparticles, created using a unique hot-wire chemical vapour deposition (HWCVD) system, were studied as active material for negative electrodes in high-energy lithium ion batteries. Transmission electron microscopy (TEM), surface area analysis (BET), and X-ray diffraction (XRD) were utilized for powder characterization. Electrodes were fabricated from a slurry of MoO_3, acetylene black (AB), and polyvinylidene fluoride (PVDF) binder deposited on copper foil. Electrochemical performance was optimized as a function of pre-annealing temperature and AB:PVDF ratio. Temperature programmed desorption (TPD) and Fourier transform infrared (FTIR) spectroscopy indicated both water removal and binder decomposition during heat treatment. However, melting binder rich electrodes appeared to redistribute the conductive additive and create a uniform coating that lead to improved durability. An optimized reversible high capacity of $\sim$1050 mAh g^{-1} was obtained for an electrode fabricated from 70:10:20 active material:AB:PVDF with a 250 °C pre-heat treatment.

11/00758 Plug-in hybrid electric vehicles – a low-carbon solution for Ireland?

Smith, W. J. *Energy Policy*, 2010, 38, (3), 1485–1499.

Between 1990 and 2006, the primary energy requirement of the Irish transport sector increased by 166%. Associated greenhouse gas (GHG) emissions have followed a corresponding trajectory, and are responsible – at least in part – for Ireland's probable failure to meet its Kyoto targets. As in most countries, Ireland's transport sector is almost totally reliant on oil – a commodity for which Ireland is totally dependent on imports – and therefore vulnerable to supply and price shocks. Conversely, the efficiency and carbon intensity of the Irish electricity supply system have both improved dramatically over the same period, with significant further improvements projected over the coming decade. This paper analyses the prospects for leveraging these changes

by increasing the electrification of the Irish transport sector. Specifically, the potential benefits of plug-in hybrid-electric vehicles (PHEV) are assessed, in terms of reducing primary energy requirement (PER) and CO_2 emissions. It is shown that, on a per-km basis, PHEV offer the potential for reductions of 50% or more in passenger car PER and CO_2 intensity. However, the time required to turn over the existing fleet means that a decade or more will be required to significantly impact PER and emissions of the PC fleet.

12 REFRACTORIES/ CERAMICS

Properties, production, applications

11/00759 A silica supported Fe–Co bimetallic catalyst prepared by the sol/gel technique: operating conditions, catalytic properties and characterization

Mirzaei, A. A. *et al. Fuel Processing Technology*, 2010, 91, (3), 335–347.
A Co/Fe catalyst was prepared using the sol/gel technique in order to study its catalytic activity and selectivity in the Fischer–Tropsch synthesis. The effect of a range of operation variables such as pressure, temperature and H_2/CO molar feed ratio on the catalytic performance of 40%Fe/60%Co/15 wt%SiO_2/1.5 wt%K catalyst was investigated. It was found that the optimum operating conditions is a $H_2/CO = 2/1$ molar feed ratio at 350 °C temperature and 3 bar pressure. Characterization of both precursor and calcined catalysts was carried out using XRD, SEM, EDS, TPR, BET surface area measurements and thermal analysis methods such as TGA and DSC. It was observed that all of the different operation variables influenced the structure, morphology and catalytic performance of the catalysts.

11/00760 Effect of BaO addition on magnesium lanthanum alumino borosilicate-based glass-ceramic sealant for anode-supported solid oxide fuel cell

Ghosh, S. *et al. International Journal of Hydrogen Energy*, 2010, 35, (1), 272–283.
The authors report the effect of BaO addition on thermal, crystallization, electrical and mechanical behaviour of the magnesium lanthanum alumino borosilicate glass-ceramics. The glass forming region has been found to be quite narrow with respect to BaO content. Casting and annealing of completely transparent and amorphous glasses within this system has been possible only at an optimum BaO content of 25 mol% without any La_2O_3 and Al_2O_3. On further optimization of the developed glasses in terms of different borosilicate ratios, one of the developed compositions having MgO and BaO content of 22 and 25 mol% respectively, with a glass former ratio of 3 (SiO_2:B_2O_3) has been found to be quite promising in terms of its mechanical property, excellent joining, minimum chemical interaction and lowest leak-rate with the metallic interconnect such as Crofer22-APU, and thus fulfills the major requirements for SOFC sealing application.

11/00761 Electrical behavior of aluminosilicate glass-ceramic sealants and their interaction with metallic solid oxide fuel cell interconnects

Goel, A. *et al. Journal of Power Sources*, 2010, 195, (2), 522–526.
A series of alkaline-earth aluminosilicate glass-ceramics (GCs) were appraised with respect to their suitability as sealants for solid oxide fuel cells (SOFCs). The parent composition with general formula $Ca_{0.9}MgAl_{0.1}La_{0.1}Si_{1.9}O_6$ was modified with Cr_2O_3 and BaO. The addition of BaO led to a substantial decrease in the total electrical conductivity of the GCs, thus improving their insulating properties. BaO-containing GCs exhibited higher coefficient of thermal expansion (CTE) in comparison to BaO-free GCs. An extensive segregation of oxides of Ti and Mn, components of the Crofer22 APU interconnect alloy, along with negligible formation of $BaCrO_4$ was observed at the interface between GC/interconnects diffusion couples. Thermal shock resistance and gas-tightness of GC sealants in contact with yttria-stabilized zirconia electrolyte (8YSZ) was evaluated in air and water. Good matching of CTE and strong, but not reactive, adhesion to the solid electrolyte and interconnect, in conjunction with a high level of electrical resistivity, are all advantageous for potential SOFC applications.

11/00762 Fabrication and characterization of Li_3TaO_4 ceramic pebbles by wet process

Zhu, D. *et al. Journal of Nuclear Materials*, 2010, 396, (2–3), 245–250.
Lithium-containing ceramics have long been recognized as the tritium breeding materials in the fusion–fission or fusion reactor blanket. Li_3TaO_4 (lithium orthotantalate) pebbles, with high melting point (~1406 °C), good thermal stability, and high thermal conductivity, were fabricated by wet process (freeze–drying) as a new potential candidate of tritium breeder. The diameter of ceramic pebbles is 0.7–1.0 mm, density is over 90% (TD), pore diameter is 1.86 μm (a.v.), grain size is 15 μm (a.v.), crush load is up to 46.7 N (a.v.).

11/00763 Heterogeneous transesterification processes by using CaO supported on zinc oxide as basic catalysts

Alba-Rubio, A. C. *et al. Catalysis Today*, 2010, 149, (3–4), 281–287.
Zinc oxide, obtained by thermal decomposition of zinc oxalate, has been impregnated with different amounts of calcium oxide, and used as solid catalyst for transesterification processes. Catalysts have been characterized by chemical analysis, XRD, XPS, FT-IR, SEM, N_2 adsorption–desorption at 77 K and CO_2-TPD. The catalytic behaviour has been evaluated by choosing two transesterification processes: a simple model such as the reaction between ethyl butyrate and methanol and the production of biodiesel from sunflower oil and methanol. Calcium oxide is stabilized by filling the mesoporous network of ZnO, as reveal the corresponding pore size distributions, thus avoiding the lixiviation of the active phase in the reaction medium. These supported CaO catalysts, thermally activated at 1073 K, can give rise to a fatty acid methyl esters yield greater than 90%, after 2 h of reaction, when a methanol-to-oil molar ratio of 12 and 1.3 wt% of the catalyst with a 16 wt% CaO were employed.

11/00764 Nano-scale quasi-melting of alkali-borosilicate glasses under electron irradiation

Möbus, G. *et al. Journal of Nuclear Materials*, 2010, 396, (2–3), 264–271.
Quasi-melting of micro- and nano-samples during transmission electron microscope irradiation of glassy materials is analysed. Overheating and true melting by the electron beam is shown not to be an explanation due to the ultra-sharp boundary between transformed and intact material. It is proposed that the observed fluidization (quasi-melting) of glasses can be caused by effective bond breaking processes induced by the energetic electrons in the electron beam. The bond breaking processes modify the effective viscosity of glasses to a low activation energy regime. The higher the electron flux density the lower is the viscosity. Quasi-melting of glasses at high enough electron flux densities can result in shape modification of nano-sized particles including formation of perfect beads due to surface tension. Accompanying effects, such as bubble formation and foil bending are revisited in the light of the new interpretation.

11/00765 Performance of a multifunctional PV/T hybrid solar window

Davidsson, H. *et al. Solar Energy*, 2010, 84, (3), 365–372.
A building-integrated multifunctional PV/T solar window has been developed and evaluated. It is constructed of PV cells laminated on solar absorbers placed in a window behind the glazing. To reduce the cost of the solar electricity, tiltable reflectors have been introduced in the construction to focus radiation onto the solar cells. The reflectors render the possibility of controlling the amount of radiation transmitted into the building. The insulated reflectors also reduce the thermal losses through the window. A model for simulation of the electric and hot water production was developed. The model can perform yearly energy simulations where different features such as shading of the cells or effects of the glazing can be included or excluded. The simulation can be run with the reflectors in an active, up right, position or in a passive, horizontal, position. The simulation program was calibrated against measurements on a prototype solar window placed in Lund in the south of Sweden and against a solar window built into a single family house, Solgården, in Älvkarleö in the central part of Sweden. The results from the simulation shows that the solar window annually produces about 35% more electric energy per unit cell area compared to a vertical flat PV module.

11/00766 Phase composition of alumina–mullite–zirconia refractory materials

Zanelli, C. *et al. Journal of the European Ceramic Society*, 2010, 30, (1), 29–35.
Refractories in the Al_2O_3–SiO_2–ZrO_2 system are widely used in many applications, for ceramic rollers in particular, and are characterized by high mechanical strength, excellent thermal shock resistance, resistance to corrosion by alkaline compounds and low creep at high temperature. Their performances greatly depend on the amount and chemical composition of crystalline and glassy phases, which were investigated by quantitative XRPD (RIR–Rietveld) and XRF in order to assess the effect of various Al_2O_3/SiO_2 ratios of starting batches and

different alumina particle size distributions. Refractories consist of mullite, corundum, zirconia polymorphs and a vitreous phase in largely variable amounts. The mullite percentage, unit cell parameters and composition vary with sintering temperature, being mostly influenced by the Al_2O_3/SiO_2 ratio of the batch. Its orthorhombic unit cell increased its volume from 1400 to 1500 °C, while its stoichiometry became more aluminous. The corundum stability during firing is strongly affected by the Al_2O_3/SiO_2 ratio, but not by the particle size distribution of alumina raw materials. Zirconia raw materials are involved in the high temperature reactions and about one-third of the available ZrO_2 is dissolved in the glassy phase, ensuring excellent resistance to alkali corrosion, mainly depending on the fraction of coarse alumina. The phase composition of the vitreous phase increased with sintering temperature, being over 20% when the fractions of coarse alumina in the starting batch are between 0.2 and 0.5.

11/00767 Reactive ion etching (RIE) technique for application in crystalline silicon solar cells
Yoo, J. *Solar Energy*, 2010, 84, (4), 730–734.
Saw damage removal (SDR) and texturing by conventional wet chemical processes with alkali solution etch about 20 micron of silicon wafer on both sides, resulting in thin wafers with which solar cell processing is difficult. Reactive ion etching (RIE) for silicon surface texturing is very effective in reducing surface reflectance of thin crystalline silicon wafers by trapping the light of longer wavelength. High efficiency solar cells were fabricated during this study using optimized RIE. Saw damage removal (SDR) with acidic mixture followed by RIE-texturing showed the decrease in silicon loss by ~67% and ~70% compared to conventional SDR and texturing by alkaline solution. Also, the crystalline silicon solar cells fabricated by using RIE-texturing showed conversion efficiency as high as 16.7% and 16.1% compared with 16.2%, which was obtained in the case of the cell fabricated with SDR and texturing with NaOH solution.

11/00768 The calculation and analysis of glass-to-metal sealing stress in solar absorber tube
Lei, D. *et al. Renewable Energy*, 2010, 35, (2), 405–411.
The failure or degradation of solar absorber tubes is the single largest cost factor for current parabolic trough solar power plant. The main failure reason is that there are residual stresses in the glass-to-metal joints which are generated during the cooling process of sealing. According to the thin shell theory and thermal stress theory, this paper presents the analytic solution for the glass-to-metal sealing residual stress. It also analyses how the thickness of glass tube, thickness of metal ring, and thermal expansion coefficient affect the residual stress distribution. In order to verify the calculation results, the photoelastic technique is used to measure the residual stress and the tensile test is used to obtain the point of the most dangerous stress and the tensile strength for the sealed specimens. It can be concluded that the maximum tensile stress happens at some distance near the sealing interface on the outer surface of glass tube. The seal strength increases when the thickness of the glass tube is increased. The analytic solution is proved feasible to analyse the residual stress of glass-to-metal seals in solar absorber tubes.

11/00769 The modification of SiO_2 by various organic groups and its influence on the properties of cobalt-based catalysts for Fischer–Tropsch synthesis
Shi, L. *et al. Fuel Processing Technology*, 2010, 91, (4), 394–398.
SiO_2 was modified by various organic groups before the impregnation of cobalt precursor. These modified supports and the corresponding catalysts were characterized by BET, ^{29}Si CP MAS NMR, XRD, Raman, XPS and H_2-TPR. These characterizations clearly show the changes of morphology as well as reducibility of the catalysts. The organic modification of SiO_2 remarkably influences the reducibility and catalytic properties of Co catalysts. Co catalyst supported on $(CH_3)_3$-modified SiO_2 exhibits high activity and C_5^+ hydrocarbon selectivity. However, COOH-, NH_2-, and $NH_2(CH_2)_2NH$-modified SiO_2 distinctly suppress the catalytic activity of Co catalysts.

11/00770 Thermal performance analysis of an electrochromic vacuum glazing with low emittance coatings
Fang, Y. *et al. Solar Energy*, 2010, 84, (4), 516–525.
Thermal performance of an electrochromic (EC) vacuum glazing (VG) was modelled under ASTM standard winter conditions. The EC VG comprised three 0.5 m by 0.5 m glass panes with a 0.12 mm wide evacuated space between two 4 mm thick panes sealed contiguously by a 6 mm wide indium based edge seal with either one or two low-emittance (low-e) coatings supported by a 0.32 mm diameter square pillar grid spaced at 25 mm. The third glass pane on which the 0.1 mm thick EC layer was deposited was sealed to the evacuated glass unit. The whole unit was rebated by 10 mm within a solid wood frame. The low-e coating absorbed 10% of solar energy incident on it. With the EC VG installed with the EC component facing the outdoor environment, for an incident solar radiation of 300 $W m^{-2}$, simulations demonstrated that when the EC layer is opaque for winter conditions, the temperature of the inside glass pane is higher than the indoor air temperature, due to solar radiation absorbed by the low-e coatings and the EC layer, the EC VG is a heat source with heat transferred from the glazing to the interior environment. When the emittance was lower to 0.02, the outdoor and indoor glass pane temperatures of the glazing with single and two low-e coatings are very close to each other. For an insolation of 1000 $W m^{-2}$, the outdoor glass pane temperature exceeds the indoor glass pane temperature, consequentially the outdoor glass pane transfers heat to the indoor glass pane.

13 ALTERNATIVE ENERGY SUPPLIES

Biofuels and bioconversion energy

11/00771 A multi-criteria approach to screening alternatives for converting sewage sludge to biodiesel
Pokoo-Aikins, G. *et al. Journal of Prevention in the Process Industries*, 2010, 23, (3), 412–420.
The search for cheaper feedstock for use in the production of biofuels such as biodiesel has turned its attention to various forms of waste products including animal fats, waste oils and now lipids in sludge. With the potential of obtaining sludge at a reduced cost, free, or possibly with incentives, sewage sludge is being investigated as a potential feedstock for biofuel production. For the extraction of oils from the sewage sludge and the subsequent processing, there are various alternatives that should be designed, analysed, and screened. In developing and screening these alternatives, it is necessary to have a consistent basis for comparing alternatives based on key criteria. While most of the design studies focus on techno-economic criteria, it is also important to include safety metrics in the multicriteria analysis. In this work, a detailed economic analysis and a safety evaluation are performed on a process involving extraction of triglycerides and fatty acids, pre-treatment of fatty acids (direct conversion to biodiesel), and transesterification of triglycerides to biodiesel. Four solvents, toluene, hexane, methanol and ethanol, are individually used in the extraction process. The resulting triglycerides and fatty acids from each extraction are modelled in the pre-treatment process. ASPEN Plus software is used to simulate the detailed process. Economic analysis is performed using ASPEN ICARUS, and scale-up of a previously analysed process is used to estimate the cost of the biodiesel portion of the process. A new safety metric (referred to as the safety index, SI) is introduced to enable comparison of the various solvent extraction processes. The SI is based on solvent criteria as well as process conditions. A case study is presented to demonstrate the insights and usefulness of the developed approach. The results of the techno-economic analysis reveal that of the four solvents used for the initial extraction, hexane and toluene were least costly ($2.89 and $2.79/gallon, respectively). Conversely, the safety analysis utilizing the SI reveals that methanol and ethanol are the safer solvent options. The issue of cost/safety tradeoffs is also discussed.

11/00772 A review on biodiesel production using catalyzed transesterification
Leung, D. Y. C. *et al. Applied Energy*, 2010, 87, (4), 1083–1095.
Biodiesel is a low-emissions diesel substitute fuel made from renewable resources and waste lipid. The most common way to produce biodiesel is through transesterification, especially alkali-catalysed transesterification. When the raw materials (oils or fats) have a high percentage of free fatty acids or water, the alkali catalyst will react with the free fatty acids to form soaps. The water can hydrolyse the triglycerides into diglycerides and form more free fatty acids. Both of the above reactions are undesirable and reduce the yield of the biodiesel product. In this situation, the acidic materials should be pre-treated to inhibit the saponification reaction. This paper reviews the different approaches of reducing free fatty acids in the raw oil and refinement of crude biodiesel that are adopted in the industry. The main factors affecting the yield of biodiesel, i.e. alcohol quantity, reaction time, reaction temperature and catalyst concentration, are discussed. This paper also described other new processes of biodiesel production. For instance, the Biox co-solvent process converts triglycerides to esters through the selection of inert co-solvents that generates a one-phase oil-rich system. The non-catalytic supercritical methanol process is advantageous in terms of shorter reaction time and lesser purification steps but requires high temperature and pressure. For the *in situ* biodiesel

process, the oilseeds are treated directly with methanol in which the catalyst has been preciously dissolved at ambient temperatures and pressure to perform the transesterification of oils in the oilseeds. This process, however, cannot handle waste cooking oils and animal fats.

11/00773 An ideal feedstock, kusum (*Schleichera triguga*) for preparation of biodiesel: optimization of parameters

Sharma, Y. C. and Singh, B. *Fuel*, 2010, 89, (7), 1470–1474.

Kusum (*Schleichera triguga*), a non-edible oil bearing plant has been used as an ideal feedstock for biodiesel development in the present study. Various physical and chemical parameters of the raw oil and the fatty acid methyl esters derived have been tested to confirm its suitability as a biodiesel fuel. The fatty acid component of the oil was tested by gas chromatography. The acid value of the oil was determined by titration and was found to 21.30 mg KOH/g which required two step transesterification. Acid value was brought down by esterification using sulfuric acid (H_2SO_4) as a catalyst. Thereafter, alkaline transesterification was carried out using potassium hydroxide (KOH) as catalyst for conversion of kusum oil to its methyl esters. Various parameters such as molar ratio, amount of catalyst and reaction time were optimized and a high yield (95%) of biodiesel was achieved. The high conversion of the feedstock into esters was confirmed by analysis of the product on gas chromatograph–mass spectrometer (GC–MS). Viscosity and acid value of the product biodiesel were determined and found to be within the limits of ASTM D 6751 specifications. Elemental analysis of biodiesel showed presence of carbon, hydrogen, oxygen and absence of nitrogen and sulfur after purification. Molar ratio of methanol to oil was optimized and found to be 10:1 for acid esterification, and 8:1 for alkaline transesterification. The amounts of H_2SO_4 and KOH, 1% (v/v) and 0.7% (w/w), respectively, were found to be optimum for the reactions. The time duration of 1 h for acid esterification followed by another 1 h for alkaline transesterification at $50 \pm 0.5\,^{\circ}C$ was optimum for synthesis of biodiesel.

11/00774 Bio-butanol: combustion properties and detailed chemical kinetic model

Black, G. *et al. Combustion and Flame*, 2010, 157, (2), 363–373.

Autoignition delay time measurements were performed at equivalence ratios of 0.5, 1 and 2 for butan-1-ol at reflected shock pressures of 1, 2.6 and 8 atm at temperatures from 1100 to 1800 K. High-level *ab initio* calculations were used to determine enthalpies of formation and consequently bond dissociation energies for each bond in the alcohol. A detailed chemical kinetic model consisting of 1399 reactions involving 234 species was constructed and tested against the delay times and also against recent jet-stirred reactor speciation data with encouraging results. The importance of enol chemistry is highlighted.

11/00775 Biodiesel from jatropha: can India meet the 20% blending target?

Biswas, P. K. *et al. Energy Policy*, 2010, 38, (3), 1477–1484.

The need for biofuels, particularly liquid ones like ethanol and biodiesel, has been felt by most of the countries and their governments have been trying to promote these fuels. Following in line with global trend, India declared its biofuel policy in which biodiesel, primarily from jatropha, would meet 20% of the diesel demand beginning with 2011–2012. In spite of the efforts made by the state, production of biodiesel, however, has not picked up at all. Doubt arises as to whether the country will be able to meet the target. It is felt that the government policy, particularly regarding land utilization, organizing cultivation of jatropha and pricing of jatropha seeds, needs to be more clear. This paper attempts to make an assessment of the state of India's biofuel programme and to identify the hurdles that policy-maker need to overcome to achieve the goal.

11/00776 Biodiesel production from supercritical carbon dioxide extracted Jatropha oil using subcritical hydrolysis and supercritical methylation

Chen, C.-H. *et al. The Journal of Supercritical Fluids*, 2010, 52, (2), 228–234.

This study investigates supercritical carbon dioxide ($SC\text{-}CO_2$) extraction of triglycerides from powdered *Jatropha curcas* kernels followed by subcritical hydrolysis and supercritical methylation of the extracted $SC\text{-}CO_2$ oil to obtain a 98.5% purity level of biodiesel. Effects of the reaction temperature, the reaction time and the solvent to feed ratio on free fatty acids in the hydrolysed oil and fatty acid esters in the methylated oil via two experimental designs were also examined. Supercritical methylation of the hydrolysed oil following subcritical hydrolysis of the $SC\text{-}CO_2$ extract yielded a methylation reaction conversion of 99%. The activation energy of hydrolysis and transesterified reactions were 68.5 and 45.2 kJ/mole, respectively. This study demonstrates that supercritical methylation preceded by subcritical hydrolysis of the $SC\text{-}CO_2$ oil is a feasible two-step process in producing biodiesel from powdered Jatropha kernels.

11/00777 Calcined sodium silicate as solid base catalyst for biodiesel production

Guo, F. *et al. Fuel Processing Technology*, 2010, 91, (3), 322–328.

This paper examined the use of calcined sodium silicate as a novel solid base catalyst in the transesterification of soybean oil with methanol. The calcined sodium silicate was characterized by DTA-TG, Hammett indicator method, XRD, SEM, BET, IR and FT-IR. It catalysed the transesterification of soybean oil to biodiesel with a yield of almost 100% under the following conditions: sodium silicate of 3.0 wt%, a molar ratio of methanol/oil of 7.5:1, reaction time of 60 min, reaction temperature of 60 °C, and stirring rate of 250 rpm. The oil containing 4.0 wt% water or 2.5 wt% FFA could also be transesterified by using this catalyst. The catalyst can be reused for at least five cycles without loss of activity.

11/00778 Characterization of beef tallow biodiesel and their mixtures with soybean biodiesel and mineral diesel fuel

Teixeira, L. S. G. *et al. Biomass and Bioenergy*, 2010, 34, (4), 438–441.

Tallow is a raw material for biodiesel production that, due to their highly centralized generation in slaughter/processing facilities and historically low prices, may have energy, environmental, and economic advantages that could be exploited. However beef tallow biodiesel have unfavourable properties due the presence of high concentration of saturated fatty esters. One way to overcome these inconveniences is using blending procedures. In this way, blends of beef tallow biodiesel with soybean biodiesel and with conventional mineral diesel fuel were prepared and the quality of the mixtures was monitored with the purpose to study ideal proportions of the fuels. By measurement of the viscosity, density, cold filter plugging point, and flash point, it was demonstrated that tallow biodiesel can be blended with both mineral diesel and soybean biodiesel to improve the characteristics of the blend fuels, over that of the tallow.

11/00779 Dual bed reactor for the study of catalytic biomass tars conversion

Ammendola, P. *et al. Experimental Thermal and Fluid Science*, 2010, 34, (3), 269–274.

A dual fixed-bed laboratory scale set-up has been used to compare the activity of a novel $Rh/LaCoO_3/Al_2O_3$ catalyst to that of dolomite, olivine and Ni/Al_2O_3, typical catalysts used in fluidized bed biomass gasification, to convert tars produced during biomass devolatilization stage. The experimental apparatus allows the catalyst to be operated under controlled conditions of temperature and with a real gas mixture obtained by the pyrolysis of the biomass carried out in a separate fixed bed reactor operated under a selected and controlled heating up rate. The proposed catalyst exhibits much better performances than conventional catalysts tested. It is able to completely convert tars and also to strongly decrease coke formation due to its good redox properties.

11/00780 Ethanol production from corn stover hemicellulosic hydrolysate using immobilized recombinant yeast cells

Zhao, J. and Xia, L. *Biochemical Engineering Journal*, 2010, 49, (1), 28–32.

Ethanol production from corn stover hemicellulosic hydrolysate was investigated using immobilized recombinant *Saccharomyces cerevisiae* yeast cells. Detoxification of hemicellulosic hydrolysate by roto-evaporation and lime neutralization was carried out to remove volatile fermentation inhibitors. All furfural and more than 50% acetic acid in the hydrolysate were removed, meanwhile the xylose concentration was enhanced to 71.8 g/L. The fermentability of the detoxified hydrolysate was significantly improved using immobilized cells of recombinant *S. cerevisiae* by Ca-alginate. An ethanol concentration of 31.1 g/L and the corresponding ethanol yield on fermentable sugars of 0.406 g/g were obtained within 72 h in batch fermentation of the detoxified hydrolysate with immobilized cells. In addition, repeated batch fermentation of immobilized recombinant *S. cerevisiae* cells was attempted for ethanol production for 5 batches. The concentration of ethanol in each batch maintained above 30.1 g/L with the ethanol yield on fermentable sugars over 0.393 g/g. These results demonstrate the viability and significance of ethanol production from corn stover hemicellulosic hydrolysate.

11/00781 Feasibility study of a thermally coupled reactive distillation process for biodiesel production

Gomez-Castro, F. I. *et al. Chemical Engineering and Processing: Process Intensification*, 2010, 49, (3), 262–269.

Biodiesel fuel represents an interesting alternative as a clean and renewable substitute of fossil fuels. A typical biodiesel production process involves the use of a catalyst, which implies high energy consumption for the separation of the catalyst and the by-products of the reaction, including those of undesirable side reactions (such as the saponification reaction). A recently proposed process involves the use of short-chain alcohols at supercritical conditions, avoiding the use of a

catalyst and the occurrence of the saponification reaction. This process requires fewer pieces of equipment than the conventional one, but its high energy requirements and the need of special materials that support the reaction conditions makes the main product, biodiesel fuel, more expensive than petroleum diesel. In this work, a modification of the supercritical process for the production of biodiesel fuel is proposed. Two alternatives are proposed. The process involves the use of either reactive distillation or thermally coupled reactive distillation. Simulations have been carried out by using the Aspen One™ process simulator to demonstrate the feasibility of such alternatives to produce biodiesel with methanol at high-pressure conditions. A design method for the thermally coupled system is also proposed. Both systems have been tested and the results indicate favourable energy performance when compared to the original scheme. Furthermore, the thermally coupled system shows lower energy consumptions than the reactive distillation column.

11/00782 In-field direct combustion fuel property changes of switchgrass harvested from summer to fall

Ogden, C. A. *et al. Fuel Processing Technology*, 2010, 91, (3), 266–271.
Switchgrass, a perennial warm-season grass and potential energy crop, is usually harvested during the time between full maturity in the fall to the following spring. During this wide harvest window, the changes in fuel properties that could occur are important for making appropriate decisions with respect to the optimum harvest time for maximum fuel quality. A field plot study was carried out to investigate the quantitative fuel properties (proximate, ultimate and mineral analyses) of switchgrass over a harvest period from crop maturity in July through November. Harvest moisture decreased from July to November and moisture was uniformly distributed in the switchgrass plant at all times in the harvest period. There were significant differences in ash, volatiles, fixed carbon and nitrogen among months of harvest. Nitrogen, ash and fixed carbon contents decreased while oxygen and volatiles increased through the harvest period. Also, there were significant differences in oxides of silicon, calcium, potassium, phosphorus and sulfur among harvest times. The concentration of oxides of potassium and sulfur decreased at the end of the harvesting period. Fouling and slagging indices decreased as harvest was delayed but remained low throughout harvest. However, the decreases are small and might not dramatically impact fouling and slagging. Overall, the results appear to favour a later harvest for switchgrass used for direct combustion. This study will benefit feedstock producers as well as biomass feedstock facility operators by providing a better understanding of how the properties of switchgrass vary over a typical harvest period and their potential effect on boiler equipment.

11/00783 Mapping the expansion and distribution of willow plantations for bioenergy in Sweden: lessons to be learned about the spread of energy crops

Mola-Yudego, B. and González-Olabarria, J. R. *Biomass and Bioenergy*, 2010, 34, (4), 442–448.
Where and when farmers will adopt new energy crops is a key issue for the proper development of a country's energy strategy on renewables based in bioenergy. This paper analyses the spread of willow cultivation for bioenergy in Sweden, during the period 1986–2005, linked to the changes in the policies of promotion of wood-energy crops and to the local economic framework. To perform the study, a geostatistic method based on kernel analysis is applied, in order to identify the spatial grouping patterns of growers and plantations, and the areas where cultivation was successful. The analysis of the resulting figures shows that the development of an infrastructure and a market for willow chips are essential pre-conditions for the development of short rotation coppice for bioenergy. The results of this study confirm that probably the most important factor in the location of willow plantations is the existence of consumers that can guarantee a long-term demand for willow chips. The tools and methods presented, and its analysis, can provide a better understanding of the interactions between the biomass producers, the energy consumers and the different local and national actors.

11/00784 Modeling and optimization of biogas production from a waste digester using artificial neural network and genetic algorithm

Abu Qdais, H. *et al. Resources, Conservation and Recycling*, 2010, 54, (6), 359–363.
Artificial neural networks (ANNs) and genetic algorithms (GA) are considered among the latest tools that are used to solve complicated problems that cannot be solved by conventional solutions. The present study utilizes the ANN and GA as tools for simulating and optimizing of biogas production process from the digester of Russaifah biogas plant in Jordan. Operational data of the plant for a period of 177 days were collected and employed in the analysis. The study considered the effect of digester operational parameters, such as temperature (T), total solids (TS), total volatile solids (TVS), and pH on the biogas yield. A multi-layer ANN model with two hidden layers was trained to simulate the digester operation and to predict the methane production. The performance of the ANN model is verified and demonstrated the effectiveness of the model to predict the methane production accurately with correlation coefficient of 0.87. The developed ANN model was used with genetic algorithm to optimize the methane size. The optimal amount of methane was converged to be 77%, which is greater than the maximum value obtained from the plant records of 70.1%. The operational conditions that resulted in the optimal methane production were determined as temperature at 36 °C, TS 6.6%, TVS 52.8% and pH 6.4.

11/00785 Molecular thermodynamics of biodiesel fuel compounds

Perdomo, F. A. and Gil-Villegas, A. *Fluid Phase Equilibria*, 2010, 293, (2), 182–189.
Biodiesel fuel is a biodegradable clean energetic resource comprised by a mixture of monoalkyl esters of long-chain fatty acids that can be obtained from a wide variety of raw materials. In terms of sulfur content, flash point, aromatic content, biodegradability and low emission of greenhouse gases effect, biodiesel fuel is better than diesel fuel. This paper presents a molecular-thermodynamic modelling of the phase equilibria of three very common long-chain alkylesters biodiesel compounds: methyl cis-9-octadecenoate (methyl oleate), methyl hexadecanoate (methyl palmitate) and methyl cis,cis,cis-9,12,15-octadecatrienoate (methyl linolenate). For all the cases, molecules are represented as chains of spherical segments that can associate due to the presence of short-ranged attractive sites. These attractive sites as well as the intermolecular interaction between monomer segments are modelled via square-well potentials of variable range (SW), following the statistical associating fluid theory for potentials of variable range. The optimized values of the parameters for each pure component are obtained by fitting to vapour pressure and saturated liquid densities data, derived from empirical Helmholtz free energy. Predictions are improved by the use of a discrete potential, instead of a SW potential, to represent segment–segment interactions, that can be tuned to give an optimized description of the liquid–vapour coexistence properties. The results obtained can be used to model reacting systems to produce biodiesel, based on esterification of fatty acids in presence of acid catalyst or on the transesterification with basic catalyst.

11/00786 Multi-objective process optimization and integration for the sequential and increased production of biomass, lipase and endospores of a probiotic bacterium

Das, S. *et al. Biochemical Engineering Journal*, 2010, 50, (1–2), 77–81.
The objective of this study was to substantially enhance the yields of lipase, biomass and spores from a sporogenous probiotic bacterium, *Bacillus coagulans* RK-02 by multivariate response surface modelling and genetic algorithm-based optimization. The effect of temperature, agitation and aeration on time course of growth, lipase formation and sporulation of individual batch cultivation were also studied. The optimum conditions for three responses were found to be different from each other. Comparatively lower temperature and higher agitation and aeration were needed for biomass and lipase production than that for maximizing sporulation rate. In the final validation experiment, three different optimal conditions for maximizing each of these responses, namely biomass, lipase and spore yields, in a stage wise manner were maintained respectively. This strategy produced 6.25 g L^{-1} biomass, 6×10^{12} spores per gram of biomass, and maximum of 13.46 IU lipase. Such high yield of biomass, lipase and spore from batch cultivation is first ever to be reported.

11/00787 Performance and emission characteristics of biofuel in a small-scale gas turbine engine

Habib, Z. *et al. Applied Energy*, 2010, 87, (5), 1701–1709.
Performance and emissions characteristics of a 30 kW gas turbine engine burning Jet A, soy methyl ester, canola methyl ester, recycled rapeseed methyl ester, hog-fat biofuel, and their 50% (volume) blends in Jet A were studied over a range of throttle settings. The addition of biofuel resulted in a reduction in static thrust and thrust-specific fuel consumption, and increased thermal efficiency. The CO and NO emissions from the turbine were reduced with the biofuel blends. The results suggest that an optimum mixture may be found that reduces pollutant emissions while producing the desired thrust. This study demonstrates that biofuels may serve as viable supplements to petroleum-based fuels.

11/00788 Retrofit of distillation columns in biodiesel production plants

Nguyen, N. and Demirel, Y. *Energy*, 2010, 35, (4), 1625–1632.
In this study, column grand composite curves and the exergy loss profiles produced by the Column-Targeting Tool of the Aspen Plus simulator were used to assess the performance of the existing distillation columns, and reduce the costs of operation by appropriate retrofits in a biodiesel production plant. The effectiveness of the

retrofits was assessed by means of thermodynamics and economic improvements. This study considered a biodiesel plant utilizing three distillation columns to purify biodiesel (fatty acid methyl ester) and byproduct glycerol as well as reduce the waste. The assessments of the base case simulation have indicated the need for modifications for the distillation columns. For column T202, the retrofits consisting of a feed preheating and reflux ratio modification have reduced the total exergy loss by 47%, while T301 and T302 columns exergy losses decreased by 61% and 52%, respectively. After the retrofits, the overall exergy loss for the three columns decreased from 7491.86 kW to 3627.97 kW. The retrofits required a fixed capital cost of approximately $239,900 and saved approximately $1,900,000/year in electricity costs. The retrofits have reduced the consumption of energy considerably, and provided a more environmentally friendly operation for the biodiesel plant considered.

11/00789 Sorption properties of active carbons obtained from walnut shells by chemical and physical activation

Nowicki, P. *et al. Catalysis Today*, 2010, 150, (1–2), 107–114.

A method for obtaining active carbon from common walnut shells is described. The effect of activation methods, temperature and heating mode on the shells' surface properties has also been tested. The resulting carbons were characterized by elemental analysis, low-temperature nitrogen sorption and determination of the number of surface oxygen groups. The sorption properties of the active carbons obtained were characterized by determination of nitrogen dioxide adsorption in dry conditions and the number of iodine adsorption. The final products were microporous active carbons of well-developed surface area reaching to 2305 m^2/g and pore volume to 1.15 cm^3/g, showing diverse acid–base character of the surface. The results have shown that the important effect on the content and type of surface oxides generated on the surface of the active carbons have both the temperature and the method of activation. The results obtained in this study have proved that a suitable choice of the activation procedure for walnut shells can produce activated carbons with high capacity of nitrogen dioxide, reaching to 66 mg NO_2/g. The results of the study have also shown that the adsorption ability of carbonaceous sorbents depends on the method and procedure of activation as well as on their textural parameters and acid–base properties of their surface.

11/00790 Steam reforming of biogas mixtures with a palladium membrane reactor system

Sato, T. *et al. Chemical Engineering Science*, 2010, 65, (1), 451–457.

A fundamental study of the steam reforming of biogas and that derived from supercritical water gasification of glucose was conducted with a hydrogen-permeable palladium–silver membrane reactor. The hydrogen permeabilities for H_2–H_2O (4:1), H_2–CO_2 (4:1) and H_2–N_2 (4:1) mixtures from 573 to 673 K were compared with those in the presence of hydrogen only. Water and nitrogen did not affect hydrogen permeability, whereas carbon dioxide tended to suppress its permeation in the high pressure region. Steam reforming of test gas 1 (moles H_2:CH_4:CO_2 = 50:10:40) and test gas 2 (moles H_2:CH_4:CO_2 = 10:40:50) mixtures having compositions expected from supercritical water gasification was carried out in the presence of 2 wt% Ru/Al_2O_3 at 723 K and pressures up to 0.5 MPa. Methanation was dominant and slightly decreased as hydrogen permeated through the membrane in the steam reforming of the hydrogen-rich mixture (test gas 1), whereas there was almost no effect of the membrane reactor for methane-rich mixture (test gas 2). A new system combined the supercritical water gasification system and steam reforming system was developed and gas formation from glucose was carried out at 673 K and 10 MPa for supercritical gasification and from 0.1 to 0.5 MPa of reaction pressure. The experiments changing the order of catalytic bed and Pd–Ag membrane in the membrane reactor for steam reforming revealed that the elevated high pressures and hydrogen removal before catalytic steam reforming are advantageous for high hydrogen recovery.

11/00791 Study of a water electrolysis system using a compact solar cell module with a plant shoot configuration

Obara, S. *International Journal of Hydrogen Energy*, 2010, 35, (1), 26–36.

The system proposed in this paper produces hydrogen by supplying photovoltaic power to a water electrolyser and then supplying this gas to a fuel cell with a time shift. The objective of this system is to supply power to an individual house or apartment building with only green energy. However, the solar cell module installation area is large in the proposed system. Therefore, this paper considered installing a solar cell module with a plant shoot configuration. As a result of this modification, the power generation area of the proposed system is 33–52% smaller than that of a conventional flat solar cell module. From these results, it should be possible to introduce the proposed system into an individual house.

11/00792 Study of hydrodynamics, mass transfer, energy consumption, and biomass production from natural gas in a forced-liquid vertical tubular loop bioreactor

Yazdian, F. *et al. Biochemical Engineering Journal*, 2010, 49, (2), 192–200.

A forced-liquid vertical tubular loop bioreactor (VTLB) has been used for the production of biomass from natural gas. Hydrodynamic characteristics and mass-transfer coefficients have been determined as functions of design and operational parameters. Energy consumption for different gas and liquid flow rates has been studied. Liquid flow rate was found to have a remarkable effect on gas hold-up and k_La due to its influence on mixing time. The values of k_La for gases have been determined for different geometrical and operational factors. New correlations for mixing time, gas hold-up, and k_La were obtained. A gas mixture of 40 vol% methane and 60 vol% air proved to be optimal for biomass production.

11/00793 The promise of a technology revolution in cassava bioethanol: from Thai practice to the world practice

Sriroth, K. *et al. Fuel*, 2010, 89, (7), 1333–1338.

The abundance of low-cost feedstock and the cost-effective technology are of great importance for reinforcing industrialization of bioethanol for fuel use as sustainably-sourced and eco-friendly energy. This paper describes improved techniques that increase the root productivity of cassava (*Manihot esculenta* Crantz) and its conversion to bioethanol by the energy-saving technology being developed in Thailand. The productivity of cassava roots can be significantly increased from 22 to 60 tons/ha simply by applying yield improved varieties and good cultivation practices; important ones are soil plowing, high stake quality, weed control, good planting and harvesting period, land conservation with organic fertilizers and water irrigation. Currently, the world production of cassava is around 220 million tons per annum with the average yield of 12 tons/ha and the total acreage of 18.5 million ha. If the root productivity increases, for instance, by 5 tons/ha, around 90 million tons of roots are produced which can be converted to 15,000 ML of ethanol by simultaneous saccharification and fermentation (SSF) process, a current production process of which cooked and enzymatically-liquefied cassava materials are subjected to saccharifying enzymes and yeasts in concert. The promising energy-saving technology for converting cassava chips to ethanol has also been introduced at a pilot scale by using a granular starch hydrolysing enzyme in an uncooked process.

11/00794 Thermal conversion of a novel biomass agricultural residue (vine shoots) into activated carbon using activation with CO_2

Valente Nabais, J. M. *et al. Journal of Analytical Applied Pyrolysis*, 2010, 87, (1), 8–13.

The use of a novel biomass precursor (vine shoot) for the production of activated carbons via carbon dioxide activation is reported. The carbons produced are all essentially microporous with apparent BET surface area and micropore volume up to 1173 $m^2\,g^{-1}$ and 0.53 $cm^3\,g^{-1}$, respectively. By XRD it was possible to identify in the activated carbon samples the presence of traces of inorganic heteroatoms such as Fe, Si, Al, K and Pb. All activated carbons produced have basic characteristics with point of zero charge always higher than 9.24. By FTIR it was possible to identify the formation on the activated carbon's surface of several functional groups, namely hydroxyls (free and phenol), ethers, quinones, lactones, pyrones and Si–H bonds.

11/00795 Turbine startup methods for externally fired micro gas turbine (EFMGT) system using biomass fuels

Al-attab, K. A. and Zainal, Z. A. *Applied Energy*, 2010, 87, (4), 1336–1341.

The concept of an externally fired micro gas turbine (EFMGT) using biomass fuels has been receiving more attention in the last two decades. However, most of the studies were conducted using computer simulation to evaluate the EFMGT systems with a lack of experimental studies. A small-scale EFMGT was developed using a vehicular turbocharger as a micro gas turbine. Different micro turbine startup methods were experimentally investigated with maximum turbine inlet temperature and pressure of about 694 °C and 2.1 bar, respectively. The difficulties experienced during the turbocharger engine startup process are reported in this paper. Driving the turbocharger shaft from the compressor side using the air flow hydraulic power was not a sufficient method for the EFMGT unlike the directly fired turbine. The only proven turbine startup method for the EFMGT is the mechanically driven turbine shaft.

11/00796 Two-step lipase catalysis for production of biodiesel

Talukder, M. M. R. *et al. Biochemical Engineering Journal*, 2010, 49, (2), 207–212.

Lipase-catalysed methanolysis of vegetable oils has attracted considerable interests for the production of biodiesel. However, the activity of lipase such as Novozym 435 (immobilized *Candida antarctica* lipase B) is negatively affected by methanol. To minimize this problem, two-step lipase catalysis was investigated. Crude palm oil (CPO), which is relatively cheaper because of avoiding refining cost, was used as the source of biodiesel. CPO was first hydrolysed to fatty acids, which was then esterified to biodiesel. *Candida rugosa* and Novozym 435 lipases were used as biocatalysts for the hydrolysis of CPO and the esterification of fatty acids, respectively. The complete conversion of CPO to fatty acids was achieved under an optimal condition of buffer to CPO ratio 1:1 (v/v), buffer pH 7.0, lipase 0.1 wt% of CPO, isooctane to CPO ratio 1:1 (v/v), temperature 30 °C, shaking speed 250 rpm and time 4 h. The methyl esterification of fatty acids with 1.2-fold stoichiometric excess of methanol reached the equilibrium after 2 h at which biodiesel yield was 98%. *C. rugosa* and Novozym 435 lipases were repeatedly used for 10 and 50 cycles, respectively without significant loss of their activities. The developed two-step process is very promising because of its feedstock flexibility: it can be used for production of biodiesel and fatty acids from crude, refined and waste oils.

Geothermal energy

11/00797 Comparison of energy efficiency between variable refrigerant flow systems and ground source heat pump systems

Liu, X. and Hong, T. *Energy and Buildings*, 2010, 42, (5), 584–589.

With the current movement towards net zero energy buildings, many technologies are promoted with emphasis on their superior energy efficiency. The variable refrigerant flow (VRF) and ground source heat pump (GSHP) systems are probably the most competitive technologies among these. However, there are few studies reporting the energy efficiency of VRF systems compared with GSHP systems. In this article, a preliminary comparison of energy efficiency between the air-source VRF and GSHP systems is presented. The computer simulation results show that GSHP system is more energy efficient than the air-source VRF system for conditioning a small office building in two selected US climates. In general, GSHP system is more energy efficient than the air-source VRV system, especially when the building has significant heating loads. For buildings with less heating loads, the GSHP system could still perform better than the air-source VRF system in terms of energy efficiency, but the resulting energy savings may be marginal.

11/00798 Criteria for use of groundwater as renewable energy source in geothermal heat pump systems for building heating/cooling purposes

Milenić, D. *et al. Energy and Buildings*, 2010, 42, (5), 649–657.

The energy development of cities in Europe is aimed at the sustainable use of renewable energy sources in order to achieve the substitution of fossil fuels and the reduction of the hazardous gas emission into the atmosphere. Geothermal resources of medium and low enthalpy in Europe being used for obtaining heat energy are providing about 6600 MW_t, currently having a growth trend of 50 MW_t annually. The use of geothermal low enthalpy, namely of subgeothermal groundwater resources, has even higher annual growth rate, and if such a trend is kept until the year 2010, the produced energy will amount about 8000 MW_t. The criteria of groundwater use as a hydrogeothermal energy resource in heat pumps are complex, and they deal with aspects of incoming temperatures and groundwater quantities. The precise limit temperature of groundwater that would separate the direct use of geothermal energy (only by the use of heat exchangers), and indirectly by the use of a heat pump has not been determined in the professional and scientific practice of Serbia so far. Taking into account the relatively small number of new flats being built in Serbia nowadays, in order to save energy it is necessary to carry out energy reconstruction of the existing flats whose number is estimated to be more than 2.8 million. By the application of subgeothermal energy and the use of heat pumps, energy consumption would be significantly reduced.

11/00799 Development of artificial neural network based heat convection algorithm for thermal simulation of large rectangular cross-sectional area earth-to-air heat exchangers

Zhang, J. and Haghighat, F. *Energy and Buildings*, 2010, 42, (4), 435–440.

An earth-to-air heat exchanger (ETAHE) is a low energy cooling and heating building component. It uses the ground's thermal storage to dampen ambient air temperature oscillations by delivering the air through a horizontally buried duct. To reduce airflow resistance, some hybrid ventilated buildings have recently adopted large cross-sectional area ducts. This paper describes the development of an artificial neural network based heat convection (ANN-HC) algorithm to predict local average Nusselt Numbers along the duct surfaces. Furthermore, the ANN-HC algorithm is integrated with a transient three-dimensional heat transfer model based on finite element analysis of heat conduction in the ground domain surrounding the ETAHE to establish a new thermal modelling method for ETAHEs. A case study is presented to demonstrate the working principle of the new method. It is shown that the method can very well simulate the interactions between an ETAHE and its environment.

11/00800 Exergoeconomic optimization of integrated geothermal system in Simav, Kutahya

Arslan, O. and Kose, R. *Energy Conversion and Management*, 2010, 51, (4), 663–676.

The aim of this study is to investigate the integrated use of the geothermal resources in the Kutahya–Simav region, Turkey. Although geothermal energy has been in use for years in the others countries, the integrated use of the geothermal fluid is new in Turkey. The high temperature level of the geothermal fluid in the Simav field makes it possible to utilize it for electricity generation, space heating and balneology. In this regard, a multiple complex has been proposed there in order to use the energy of the geothermal fluid more efficiently. Therefore, the possibility of electricity generation by a binary cycle has been preliminarily researched. After the electricity generation process, the waste geothermal fluid has been conducted to residences and greenhouses later for heating purpose in the field. In this regard, 21 different models have been formed and analysed using exergy and LCC methods. As a conclusion, the pre-feasibility study indicates that utilization of this geothermal capacity for multiple uses would be an attractive investment for Simav region.

11/00801 Experimental study on desulfurization efficiency and gas–liquid mass transfer in a new liquid-screen desulfurization system

Sun, Z. *et al. Applied Energy*, 2010, 87, (5), 1505–1512.

This paper presents a new liquid-screen gas–liquid two-phase flow pattern with discarded carbide slag as the liquid sorbent of sulfur dioxide (SO_2) in a wet flue gas desulfurization (WFGD) system. On the basis of experimental data, the correlations of the desulfurization efficiency with flue gas flow rate, slurry flow rate, pH value of slurry and liquid–gas ratio were investigated. A non-dimensional empirical model was developed which correlates the mass transfer coefficient with the liquid Reynolds number, gas Reynolds number and liquid–gas ratio (L/G) based on the available experimental data. The kinetic reaction between the SO_2 and the carbide slag depends on the pressure distribution in this desulfurizing tower, gas liquid flow field, flue gas component, pH value of slurry and liquid–gas ratio mainly. The transient gas–liquid mass transfer involving with chemical reaction was quantified by measuring the inlet and outlet SO_2 concentrations of flue gas as well as the characteristics of the liquid-screen two-phase flow. The mass transfer model provides a necessary quantitative understanding of the hydration kinetics of sulfur dioxide in the liquid-screen flue gas desulfurization system using discarded carbide slag which is essential for the practical application.

11/00802 Geothermal resources in the Asal Region, Republic of Djibouti: an update with emphasis on reservoir engineering studies

Houssein, D. E. and Axelsson, G. *Geothermics*, 2010, 39, (3), 220–227.

Three independent geothermal systems have been identified, so far, in the Asal region of the Republic of Djibouti (i.e. Gale le Goma, Fiale and South of Lake). Six deep wells have been drilled in the region, the first two in 1975 and the others in 1987–1988. Well A2 was damaged and wells A4 and A5 encountered impermeable yet very hot (340–365 °C) rocks. Wells A1, A2, A3 and A6 produce highly saline (120 g/L TDS) fluids leading to mineral scaling. Well test data indicate that the reservoir might be producing from fractured and porous zones. The estimated permeability-thickness of the deep Gale le Goma reservoir is in the 3–9 darcy-metre range. Lumped-parameter modelling results indicate that well A3 should be operated at about 20 kg/s total flow rate and that injection should be considered to reduce pressure drawdown. The estimated power generation potential of well A3 is 2.5 MWe, and that of all Asal high-temperature hydrothermal systems is between 115 and 329 MWe for a 25-year exploitation period.

11/00803 Temperature and chemical changes in the fluids of the Obama geothermal field (SW Japan) in response to field utilization

Saibi, H. and Ehara, S. *Geothermics*, 2010, 39, (3), 228–241.

Thermal waters from Quaternary volcanic rocks (predominantly andesites) discharge along faults in the Obama geothermal field of southwestern Japan. The chemistry of more than 100 thermal and ground water samples collected between 1936 and 2005 indicate that

the Na–Cl hot spring waters are a mixture of 'andesitic' magmatic, sea and meteoric waters. Mixing models and silica and cation geothermometry were used to estimate the SiO_2 and Cl composition and the temperature (~200 °C) of the reservoir fluids deep in the geothermal system. The isotopic data (^{18}O and D) are consistent with a mixed origin interpretation of the waters feeding the Obama hot springs, i.e. a large proportion of meteoric and sea waters, and a small magmatic component. Temperatures and chemical concentrations of the thermal waters were affected by the 1944–1959 salt production operations, but have recovered after closure of the salt factories; now they are similar to their pre-1940 values. In the future, the Obama geothermal field may be suitable for electric power generation, although heat and fluid extraction will require careful management to prevent or minimize reservoir cooling.

Solar energy

11/00804 Daylighting can be fluorescent: development of a fiber solar concentrator and test for its indoor illumination

Wang, C. *et al*. *Energy and Buildings*, 2010, 42, (5), 717–727.

Many limitations such as the strict dependence on beam irradiation and difficulties for wiring remain in conventional remote daylighting devices. This paper provides a brief discussion on the working theory and limitations for those conventional devices and presents a new concept developed by the first author for remote indoor daylighting. Based on the developed concept, a new device was designed and fabricated accordingly, which is an optical fibre solar concentrator consisting of a PMMA plate and 150 pieces of three-colour 1 m long Φ2 mm fluorescent fibres. This new device is mounted on a university building roof and the concentrated light is transported to a remote dark room through 10 m long Φ2 mm clear optical fibres. Outdoor testing and evaluations for remote indoor daylighting and power production have been conducted. A 6-month monitored data from 24 May 2008 to 23 November 2008 has been presented and the results reveal this new device a pleasant potential in remote indoor daylighting for large amount application in building integration.

11/00805 Design and performance evaluation of a new hybrid solar dryer for banana

Amer, B. M. A. *et al*. *Energy Conversion and Management*, 2010, 51, (4), 813–820.

A hybrid solar dryer was designed and constructed using direct solar energy and a heat exchanger. The dryer consists of solar collector, reflector, heat exchanger cum heat storage unit and drying chamber. The drying chamber was located under the collector. The dryer was operated during normal sunny days as a solar dryer, and during cloudy day as a hybrid solar dryer. Drying was also carried out at night with stored heat energy in water which was collected during the time of sunshine and with electric heaters located at water tank. The efficiency of the solar dryer was raised by recycling about 65% of the drying air in the solar dryer and exhausting a small amount of it outside the dryer. Under Mid-European summer conditions it can raise up the air temperature from 30 to 40 °C above the ambient temperature. The solar dryer was tested for drying of ripe banana slices. The capacity of the dryer was to dry about 30 kg of banana slices in 8 h in sunny day from an initial moisture content of 82% to the final moisture content of 18% (wb). In the same time it reduced to only 62% (wb) moisture content in open sun drying method. The colour, aroma and texture of the solar dried products were better than the sun drying products.

11/00806 Effect of selective coating on thermal performance of flat plate solar air heaters

El-Sebaii, A. A. and Al-Snani, H. *Energy*, 2010, 35, (4), 1820–1828.

A transient mathematical model was presented for a single pass flat plate solar air heater. This model was based on an analytical solution of the energy balance equations for various elements of the heater. The flowing air temperature was assumed to vary only in the flow direction. The thermal performance of the heater was investigated by computer simulation using the climatic conditions of Jeddah (lat. 21° 42′ N, long. 39° 11′ E), Saudi Arabia. Effects of solar radiation intensity, mass flow rate of the flowing air (m_l and the length (L) and width (b) of the absorber plat on the flowing air outlet temperature (T_{fo}) and the heater instantaneous (η_{inst}) and daily (η_d) efficiencies were studied. To improve the heater performance, effect of using absorber plates coated with various selective coating materials on the heater performance was also investigated. The best performance was achieved using nickel–tin as a selective coating material with a daily average of the instantaneous efficiency of 0.46. To validate the proposed mathematical model, the simulated results were compared with the measurements that had been performed for the heater with a black painted absorber plate under Tanta, lat. 30° 47′ N (Egypt), weather conditions. It was found that the proposed model is able to predict the T_{fo} accurately with a daily average relative percentage error of 7.7%. It was also inferred that the annual average of η_d with a nickel–tin selectively coated absorber is higher than that with a black painted absorber by 29.23%.

11/00807 Energy and exergy analyses of thin layer drying of mulberry in a forced solar dryer

Akbulut, A. and Durmuş, A. *Energy*, 2010, 35, (4), 1754–1763.

This paper is concerned with the energy and exergy analyses of the thin layer drying process of mulberry via forced solar dryer. Using the first law of thermodynamics, energy analysis was carried out to estimate the ratios of energy utilization and the amounts of energy gain from the solar air collector. However, exergy analysis was accomplished to determine exergy losses during the drying process by applying the second law of thermodynamics. The drying experiments were conducted at different five drying mass flow rate varied between 0.014 kg/s and 0.036 kg/s. The effects of inlet air velocity and drying time on both energy and exergy were studied. The main values of energy utilization ratio were found to be as 55.2%, 32.19%, 29.2%, 21.5% and 20.5% for the five different drying mass flow rate ranged between 0.014 kg/s and 0.036 kg/s. The main values of exergy loss were found to be as 10.82 W, 6.41 W, 4.92 W, 4.06 W and 2.65 W with the drying mass flow rate varied between 0.014 kg/s and 0.036 kg/s. It was concluded that both energy utilization ratio and exergy loss decreased with increasing drying mass flow rate while the exergetic efficiency increased.

11/00808 Energy dispatch fuzzy controller for a grid-independent photovoltaic system

Welch, R. L. and Venayagamoorthy, G. K. *Energy Conversion and Management*, 2010, 51, (5), 928–937.

This paper presents the development of an optimized fuzzy logic based photovoltaic (PV) energy dispatch controller using a swarm intelligence algorithm The PV system considered is grid-independent and consists of a fuzzy logic controller (FLC), PV arrays, battery storage, and two types of loads: a constant critical load and a time-varying non-critical load. The swarm intelligence applied in this paper is the particle swarm optimization (PSO) algorithm and is used to optimize both membership functions and rule set of the FLC. By using PSO algorithm, the optimized FLC is able to maximize energy to the system loads while also maintaining a higher average state of battery charge. This optimized FLC is then compared with the standard energy dispatch controller, referred to as the 'PV-priority' controller. The PV-priority controller attempts to power all loads and then charge the battery resulting on lesser number of days of power to critical loads unlike the optimized FLC.

11/00809 Energy from solar balloons

Grena, R. *Solar Energy*, 2010, 84, (4), 650–665.

Solar balloons are hot air balloons in which the air is heated directly by the sun, by means of a black absorber. The lift force of a tethered solar balloon can be used to produce energy by activating a generator during the ascending motion of the balloon. The hot air is then discharged when the balloon reaches a predefined maximum height. A preliminary study is presented, along with an efficiency estimation and some considerations on possible realistic configurations.

11/00810 Exergy analysis of micro-organic Rankine power cycles for a small scale solar driven reverse osmosis desalination system

Tchanche, B. F. *et al*. *Applied Energy*, 2010, 87, (4), 1295–1306.

Exergy analysis of micro-organic Rankine heat engines is performed to identify the most suitable engine for driving a small-scale reverse osmosis desalination system. Three modified engines derived from simple Rankine engine using regeneration (incorporation of regenerator or feedliquid heaters) are analysed through a novel approach, called exergy-topological method based on the combination of exergy flow graphs, exergy loss graphs, and thermoeconomic graphs. For the investigations, three working fluids are considered: R134a, R245fa and R600. The incorporated devices produce different results with different fluids. Exergy destruction throughout the systems operating with R134a was quantified and illustrated using exergy diagrams. The sites with greater exergy destruction include turbine, evaporator and feedliquid heaters. The most critical components include evaporator, turbine and mixing units. A regenerative heat exchanger has positive effects only when the engine operates with dry fluids; feedliquid heaters improve the degree of thermodynamic perfection of the system but lead to loss in exergetic efficiency. Although, different modifications produce better energy conversion and less exergy destroyed, the improvements are not significant enough and subsequent modifications of the simple Rankine engine cannot be considered as economically profitable for heat source temperature below 100 °C. As illustration, a regenerator increases the system's energy efficiency by 7%, the degree of thermodynamic perfection by 3.5% while the exergetic efficiency is unchanged in comparison with the simple Rankine cycle, with R600 as working fluid. The impacts of heat source temperature and pinch point

temperature difference on engine's performance are also examined. Finally, results demonstrate that energy analysis combined with the mathematical graph theory is a powerful tool in performance assessments of Rankine based power systems and permits meaningful comparison of different regenerative effects based on their contribution to systems improvements.

11/00811 German central solar heating plants with seasonal heat storage

Bauer, D. *et al*. *Solar Energy*, 2010, 84, (4), 612–623.

Central solar heating plants contribute to the reduction of CO_2-emissions and global warming. The combination of central solar heating plants with seasonal heat storage enables high solar fractions of 50% and more. Several pilot central solar heating plants with seasonal heat storage (CSHPSS) built in Germany since 1996 have proven the appropriate operation of these systems and confirmed the high solar fractions. Four different types of seasonal thermal energy stores have been developed, tested and monitored under realistic operation conditions: Hot-water thermal energy store (e.g. in Friedrichshafen), gravel-water thermal energy store (e.g. in Steinfurt–Borghorst), borehole thermal energy store (in Neckarsulm) and aquifer thermal energy store (in Rostock). In this paper, measured heat balances of several German CSHPSS are presented. The different types of thermal energy stores and the affiliated central solar heating plants and district heating systems are described. Their operational characteristics are compared using measured data gained from an extensive monitoring program. Thus long-term operational experiences such as the influence of net return temperatures are shown.

11/00812 Hydrogen production with a solar steam–methanol reformer and colloid nanocatalyst

Lee, M.-T. *et al*. *International Journal of Hydrogen Energy*, 2010, 35, (1), 118–126.

In the present study a small steam–methanol reformer with a colloid nanocatalyst is utilized to produce hydrogen. Radiation from a focused continuous green light laser (514 nm wavelength) is used to provide the energy for steam–methanol reforming. Nanocatalyst particles, fabricated by using pulsed laser ablation technology, result in a highly active catalyst with high surface to volume ratio. A small novel reformer fabricated with a borosilicate capillary is employed to increase the local temperature of the reformer and thereby increase hydrogen production. The hydrogen production output efficiency is determined and a value of 5% is achieved. Experiments using concentrated solar simulator light as the radiation source are also carried out. The results show that hydrogen production by solar steam–methanol colloid nanocatalyst reforming is both feasible and promising.

11/00813 Optimization of number of collectors for integrated PV/T hybrid active solar still

Gaur, M. K. and Tiwari, G. N. *Applied Energy*, 2010, 87, (5), 1763–1772.

The aim of this paper is to optimize the number of collectors for PV/T hybrid active solar still. The number of PV/T collectors connected in series has been integrated with the basin of solar still. The optimization of number of collectors for different heat capacity of water has been carried out on the basis of energy and exergy. Expressions of inner glass, outer glass and water temperature have been derived for the hybrid active solar system. For the numerical computations data of a summer day (22 May 2008) for Delhi climatic condition have been used. It has been observed that with increase of the mass of water in the basin increases the optimum number of collector. However the daily and exergy efficiency decreases linearly and non-linearly with increase of water mass. It has been observed that the maximum yield occurs at $N = 4$ for 50 kg of water mass on the basis of exergy efficiency. The thermal model has also been experimentally validated.

11/00814 Overview of recent advances in thermo-chemical conversion of biomass

Zhang, L. *et al*. *Energy Conversion and Management*, 2010, 51, (5), 969–982.

Energy from biomass, bioenergy, is a perspective source to replace fossil fuels in the future, as it is abundant, clean, and carbon dioxide neutral. Biomass can be combusted directly to generate heat and electricity, and by means of thermo-chemical and bio-chemical processes it can be converted into bio-fuels in the forms of solid (e.g. charcoal), liquid (e.g. bio-oils, methanol and ethanol), and gas (e.g. methane and hydrogen), which can be used further for heat and power generation. This paper provides an overview of the principles, reactions, and applications of four fundamental thermo-chemical processes (combustion, pyrolysis, gasification, and liquefaction) for bioenergy production, as well as recent developments in these technologies. Some advanced thermo-chemical processes, including co-firing/co-combustion of biomass with coal or natural gas, fast pyrolysis, plasma gasification and supercritical water gasification, are introduced. The advantages and disadvantages, potential for future applications and challenges of these processes are discussed. The co-firing of biomass and coal is the easiest and most economical approach for the generation of bioenergy on a large scale. Fast pyrolysis has attracted attention as it is to date the only industrially available technology for the production of bio-oils. Plasma techniques, due to their high destruction and reduction efficiencies for any form of waste, have great application potential for hazardous waste treatment. Supercritical water gasification is a promising approach for hydrogen generation from biomass feedstocks, especially those with high moisture contents.

11/00815 Quantifying and predicting performance of the solar dynamic buffer zone (SDBZ) curtain wall through experimentation and numerical modeling

Richman, R. and Pressnail, K. D. *Energy and Buildings*, 2010, 42, (4), 522–533.

The recent rise in the environmental and economic costs of energy demands a need to design and build more sustainable building systems. Curtain wall assemblies show great promise – the spandrel panels within them can be natural solar collectors. By using a solar dynamic buffer zone (SDBZ) in the spandrel cavity, solar energy can be efficiently gathered using the movement of air. There is a need for a numerical model capable of predicting performance of this system. This paper presents the quantification of a prototype SDBZ curtain wall system through experimental testing in a laboratory environment. Results from the experimental testing were used to validate a one-dimensional numerical model of the prototype. This research shows a SDBZ curtain wall system as an effective means of reducing building heating energy consumption. The numerical model showed good correlation with experimental results in the expected operating range of the system. Given the lack of published literature for similar systems, this research acts to validate a simple, innovative approach to collect solar energy that would otherwise be lost to the exterior using already existing components within a curtain wall. This research shows the SDBZ curtain wall has the potential to act as a significant solar collector.

11/00816 Technical and economic assessment of photovoltaic-driven desalination systems

Al-Karaghouli, A. *et al*. *Renewable Energy*, 2010, 35, (2), 323–328.

Solar desalination systems are approaching technical and cost viability for producing fresh-water, a commodity of equal importance to energy in many arid and coastal regions worldwide. Solar photovoltaics (PV) represent an ideal, clean alternative to fossil fuels, especially for remote communities such as grid-limited villages or isolated islands. These applications for water production in remote areas are the first to be nearing cost-competitiveness due to decreasing PV prices and increasing fossil fuel prices over the last five years. The electricity produced from PV systems for desalination applications can be used for electromechanical devices such as pumps or in direct-current (DC) devices. Reverse osmosis (RO) and electrodialysis (ED) desalination units are the most favourable alternatives to be coupled with PV systems. RO usually operates on alternating current (AC) for the pumps, thus requiring a DC/AC inverter. In contrast, electrodialysis uses DC for the electrodes at the cell stack, and hence, it can use the energy supplied from the PV panels with some minor power conditioning. Energy storage is critical and batteries are required for sustained operation. In this paper, the authors discuss the operational features and system designs of typical PV-RO and PV-ED systems in terms of their suitability and optimization for PV operation. For PV-RO and PV-ED systems, their electricity need, capital and operational costs, and freshwater production costs are evaluated. Ongoing and projected research and development activities are covered, with estimates of their potential economics. The feasibility of future solar desalination based on expected (or predicted) improvements in technology of the desalination and PV systems is discussed. Examples are provided for Middle East and other parts of the world.

11/00817 Thermal performance optimization of a flat plate solar air heater using genetic algorithm

Varun, and Siddhartha, *Applied Energy*, 2010, 87, (5), 1793–1799.

Thermal performance of solar air heater is low and different techniques are adopted to increase the performance of solar air heaters, such as: fins, artificial roughness, etc. In this paper an attempt has been done to optimize the thermal performance of flat plate solar air heater by considering the different system and operating parameters to obtain maximum thermal performance. Thermal performance is obtained for different Reynolds number, emissivity of the plate, tilt angle and number of glass plates by using genetic algorithm.

11/00818 Using digital imaging to assess spectral solar-optical properties of complex fenestration materials: a new approach in video–goniophotometry

Andersen, M. *et al*. *Solar Energy*, 2010, 84, (4), 549–562.

A large variety of angularly selective fenestration systems have been developed in the past two decades and show great potential in improving visual comfort while reducing energy consumption, especially when combined with spectrally selective properties. Such systems include light-redirecting glazing, shading, film coatings, reflectors and others. To assess the potential of these systems accurately and reliably, one needs to be able to predict in detail how they modify the energy, direction and spectral make-up of solar radiation. For this assessment, spectral (wavelength-dependent) bidirectional transmission or reflection distribution functions are used, usually referred to as BTDFs or BRDFs, or more generally BSDFs for scattering functions. To enable a faster, cheaper, and continuous investigation of these properties over most of the solar spectrum (400–1700 nm), an innovative goniospectrometric instrument has been created, relying on digital imaging, on light collection by an ellipsoidal half-transparent mirror, and on a filtering method in the visible range to generate spectral radiometric BSDFs. This so-called Heliodome instrument is described in this paper. It enables the performance of new fenestration technologies to be assessed in terms of lighting and solar gains management potential. The rotating table also serves as a heliodon, an architectural design tool for visualizing sunlight distribution inside a scale model and performing analyses on appropriate sun control strategies. The Heliodome's major innovations compared to other devices are to enable an analysis of both the visible and the near-infrared portions of the solar spectrum, to provide spectral as well as photometric light distribution data, and to ensure a continuous investigation of the transmitted or reflected light in a time-efficient way.

Wind energy

11/00819 A neural network based approach for wind resource and wind generators production assessment

Thiaw, L. *et al*. *Applied Energy*, 2010, 87, (5), 1744–1748.

The statistical study of wind speed measurements on a site makes it possible to determine a distribution law, needed to assess the available or recoverable wind energy potential. The classical approach consists in assimilating the distribution law to standard models, for example Weibull or Rayleigh, and in determining the parameters of the model so that it gets closest to the discrete law obtained by statistically treating the wind speed measurements. The Weibull model is the most used one and provides good results. However, the accurate determination of the wind speed distribution law constitutes a major problem. Multi-layer perceptron-type artificial neural networks, highly effective in function approximation problems, are used here for the approximation of the wind speed distribution law. The site energy characteristics have been determined by means of the neural approach and compared with those obtained by the classical method. The results show that the distribution law achieved by the neural model provides assessments closer to the discrete distribution than the Weibull model. This approach has enabled the wind energy potential on the Dakar site to be determined in a more accurate way. The models are also used to assess the amount of energy the wind generator WES18 of 80 kW power, set up at 10 m and 40 m above the ground, would produce annually.

11/00820 An intelligent maximum power extraction algorithm for hybrid wind–diesel-storage system

Kamal, E. *et al*. *International Journal of Electrical Power & Energy Systems*, 2010, 32, (3), 170–177.

This paper focuses on the development of maximum wind power extraction algorithms for variable speed wind turbines in hybrid wind–diesel storage system. The propose algorithm utilizes Takagi–Sugeno fuzzy controller. This algorithm combines the merits of: (i) the capability for dealing with nonlinear systems; (ii) the powerful LMI approach to obtain control gains; (iii) the high performance of integral controller. The algorithm maximizes the power coefficient for a fixed pitch and suddenly load changes. Moreover, it reduces the voltage ripple and stabilizes the system over a wide range of wind speed variations. The control scheme is tested for different real profiles of wind speed pattern and provides satisfactory results.

11/00821 Attitudes towards offshore wind farms – the role of beach visits on attitude and demographic and attitude relations

Ladenburg, J. *Energy Policy*, 2010, 38, (3), 1297–1304.

Presently, less than a handful of papers have analysed the attitude towards offshore wind farms in a population living in an area with offshore wind farms. This leaves the experience-based attitude and demographic relations analysis relatively unexplored. The present studies aims at covering some of that seemingly uncharted territory by analysing attitudes from a sample of more than 1000 respondents. Applying an ordered probit model, the results show general positive attitudes towards offshore wind farms and that the attitude formation seems to be a function of the gender, income, level of education, visit frequency and type of visit to the beach and the view to on-land turbines from the residence. Interestingly and perhaps the most interesting results, the observed relations between demographics and attitude are found to be dependent on the type and frequency of usage of the beach among the respondents. Attitudes towards offshore wind farms and demographic associations are thus found to be more evident in the case that respondents do use not the beach for walking on a relatively frequent basis but much weaker if the respondent use the beach on a frequent basis. However, these results are sensitive to the type of beach usage. This suggests that attitude formation towards offshore wind farms appear to be dependent on a combination of the type and frequency of use of the beach. To the author's knowledge these findings are novel, as such relation has not yet been identified in the literature. As such, the results shed light on a new angle in both the literature focusing on the opposition formation towards wind power projects in general and offshore wind farms in particular.

11/00822 Digital control and integration of a 192 MW wind farm with doubly fed induction generator into the Brazilian power system

da Silva, K. F. and Saidel, M. A. *Electric Power Systems Research*, 2010, 80, (1), 108–114.

This paper reports on design of digital control for wind turbines and its relation to the quality of power fed into the Brazilian grid on connecting to it a 192 MW wind farm equipped with doubly fed induction generators. PWM converters are deployed as vector-controlled regulated current voltage sources for their rotors, for independent control of both active and reactive power of those generators. Both speed control and active power control strategies are analysed, in the search for maximum efficiency of conversion of wind kinetic energy into electric power and enhanced quality of delivered power.

11/00823 Dynamic behavior analysis of doubly-fed induction generator wind turbines – the influence of rotor and speed controller parameters

Rahimi, M. and Parniani, M. *International Journal of Electrical Power & Energy Systems*, 2010, 32, (5), 464–477.

This paper analytically investigates the effects of system and controller parameters and operating conditions on the dynamic and transient behaviour of wind turbines (WTs) with doubly-fed induction generators (DFIGs) under voltage dips and wind speed fluctuations. Also, it deals with the design considerations regarding rotor and speed controllers. The poorly damped electrical and mechanical modes of the system are identified, and the effects of system parameters, and speed/rotor controllers on these modes are investigated by modal and sensitivity analyses. The results of theoretical studies are verified by time domain simulations. It is found that the dynamic behaviour of the DFIG-based WT under voltage dips is strongly affected by the stator dynamics. Further, it is shown that the closed loop bandwidth of the rotor current control, rotor current damping, DFIG power factor and the rotor back-emf voltages have high impact on the stator modes and consequently on the DFIG dynamic behaviour. Moreover, it is shown that the dynamic behaviour of DFIG-based WT under wind speed fluctuation is significantly dependent on the bandwidth and damping of speed control loop.

11/00824 Dynamic control of wind turbines

Kusiak, A. *et al*. *Renewable Energy*, 2010, 35, (2), 456–463.

This paper presents an intelligent wind turbine control system based on models integrating the following three approaches: data mining, model predictive control, and evolutionary computation. To enhance the control strategy of the intelligent system, a multi-objective model is proposed. The model involves five different objectives with different weights controlling the wind turbine performance. These weights are adjusted in response to the variable wind conditions and operational requirements. Three control factors, wind speed, turbulence intensity, and electricity demand are considered in eight computational scenarios. The performance of each scenario is illustrated with numerical results.

11/00825 Grid-fault ride-through analysis and control of wind turbines with doubly fed induction generators

Rahimi, M. and Parniani, M. *Electric Power Systems Research*, 2010, 80, (2), 184–195.

This paper deals with the low voltage ride-through (LVRT) control of wind turbines with doubly fed induction generators (DFIGs) under symmetrical voltage dips. The investigation first develops a mathematical formula for the rotor current and rotor voltage when DFIG is subjected to a symmetrical voltage dip. From the analysis, the reasons of rotor inrush current and factors influencing it are inferred. Then, a

control scheme enhancing the wind turbine LVRT capability is designed and simulated. The proposed control scheme consists of a nonlinear control strategy applied to the rotor-side converter and a dc-link voltage control applied to the grid-side converter. It improves the damping of DFIG transient response and minimizes oscillations of rotor current, electromagnetic torque and dc-link voltage during the generator voltage dip. It also limits the peak value of these quantities. At the end, results of theoretical analyses are verified by time domain simulations.

11/00826 Modeling and control of PMSG-based variable-speed wind turbine

Kim, H.-W. *et al. Electric Power Systems Research*, 2010, 80, (1), 46–52.
This paper presents a control scheme of a variable-speed wind turbine with a permanent-magnetic synchronous generator (PMSG) and full-scale back-to-back voltage source converter. A comprehensive dynamical model of the PMSG wind turbine and its control scheme is presented. The control scheme comprises both the wind-turbine control itself and the power-converter control. In addition, since the PMSG wind turbine is able to support actively the grid due to its capability to control independently active and reactive power production to the imposed set-values with taking into account its operating state and limits, this paper presents the supervisory reactive power control scheme in order to regulate/contribute the voltage at a remote location. The ability of the control scheme is assessed and discussed by means of simulations, based on a candidate site of the offshore wind farm in Jeju, Korea.

11/00827 Wind characteristics on the Yucatán Peninsula based on short term data from meteorological stations

Soler-Bientz, R. *et al. Energy Conversion and Management*, 2010, 51, (4), 754–764.
Due to the availability of sparsely populated and flat open terrain, the Yucatán Peninsula located in eastern México is a promising region from the perspective of wind energy development. Study of the diurnal and seasonal wind resource is an important stage in the move towards commercial exploitation of wind power in this Latin American region. An analysis of the characteristics of the wind resource of the Yucatán Peninsula is presented in this paper, based on 10 min averaged wind speed data from nine meteorological stations, between 2000 and 2007. Hourly and monthly patterns of the main environmental parameters have been examined. Highly directional behaviour was identified that reflects the influence of winds coming from the Caribbean Sea and the Gulf of México. The characteristics of the wind speed variation observed at the studied sites reflected their proximity to the coast and whether they were influenced by wind coming predominantly from over the land or predominantly from over the sea. The atmospheric stability over the eastern seas of the Yucatán Peninsula was also analysed to assess thermal effects for different wind directions. The findings were consistent with the variation in average wind speeds observed at the coastal sites where winds came predominantly from over the sea. The research presented here is to be used as a basis for a wind atlas for the Yucatán Peninsula.

11/00828 Wind farm investment risks under uncertain CDM benefit in China

Yang, M. *et al. Energy Policy*, 2010, 38, (3), 1436–1447.
China has set an ambitious target to increase its wind power capacity by 35 GW from 2007 to 2020. The country's hunger for clean power provides great opportunities for wind energy investors. However, risks from China's uncertain electricity market regulation and an uncertain energy policy framework, mainly due to uncertain clean development mechanism (CDM) benefits, prevent foreign investors from investing in China's wind energy. The objectives of this paper are to: (1) quantify wind energy investment risk premiums in an uncertain international energy policy context and (2) evaluate the impact of uncertain CDM benefits on the net present values of wind power projects. With four scenarios, this study simulates possible prices of certified emissions reductions (CERs) from wind power projects. Project net present values (NPVs) have been calculated. The project risk premiums are drawn from different and uncertain CER prices. The key findings show that uncertain CDM benefits will significantly affect the project NPVs. This paper concludes that the Chinese government needs revising its tariff incentives, most likely by introducing fixed feed-in tariffs (FITs), and re-examining its CDM-granting policy and its wind project tax rates, to facilitate wind power development and enable China to achieve its wind energy target.

11/00829 Wind tunnel and numerical study of a small vertical axis wind turbine

Howell, R. *et al. Renewable Energy*, 2010, 35, (2), 412–422.
This paper presents a combined experimental and computational study into the aerodynamics and performance of a small-scale vertical axis wind turbine (VAWT). Wind tunnel tests were carried out to ascertain overall performance of the turbine and two- and three-dimensional unsteady computational fluid dynamics (CFD) models were generated to help understand the aerodynamics of this performance. Wind tunnel performance results are presented for cases of different wind velocity, tip-speed ratio and solidity as well as rotor blade surface finish. It is shown experimentally that the surface roughness on the turbine rotor blades has a significant effect on performance. Below a critical wind speed (Reynolds number of 30,000) the performance of the turbine is degraded by a smooth rotor surface finish but above it, the turbine performance is enhanced by a smooth surface finish. Both two-bladed and three-bladed rotors were tested and a significant increase in performance coefficient is observed for the higher solidity rotors (three-bladed rotors) over most of the operating range. Dynamic stalling behaviour and the resulting large and rapid changes in force coefficients and the rotor torque are shown to be the likely cause of changes to rotor pitch angle that occurred during early testing. This small change in pitch angle caused significant decreases in performance. The performance coefficient predicted by the two-dimensional computational model is significantly higher than that of the experimental and the three-dimensional CFD model. The predictions show that the presence of the over tip vortices in the three-dimensional simulations is responsible for producing the large difference in efficiency compared to the two-dimensional predictions. The dynamic behaviour of the over-tip vortex as a rotor blade rotates through each revolution is also explored in the paper.

Others, including economics

11/00830 A comparative analysis of renewable electricity support mechanisms for Southeast Asia

Sovacool, B. *Energy*, 2010, 35, (4), 1779–1793.
This study evaluates the applicability of eight renewable electricity policy mechanisms for Southeast Asian electricity markets. It begins by describing the methodology behind 90 research interviews of stakeholders in the electricity industry. It then outlines four justifications given by respondents for government intervention to support renewables in Southeast Asia: unpriced negative externalities, counteracting subsidies for conventional energy sources, the public goods aspect of renewable energy, and the presence of non-technical barriers. The article develops an analytical framework to evaluate renewable portfolio standards, green power programs, public research and development expenditures, systems benefits charges, investment tax credits, production tax credits, tendering, and feed-in tariffs in Southeast Asia. It assesses each of these mechanisms according to the criteria of efficacy, cost effectiveness, dynamic efficiency, equity, and fiscal responsibility. The study concludes that one mechanism, feed-in tariffs, is both the most preferred by respondents and the only one that meets all criteria.

11/00831 A new PID controller design for automatic generation control of hydro power systems

Khodabakhshian, A. and Hooshmand, R. *International Journal of Electrical Power & Energy Systems*, 2010, 32, (5), 375–382.
This paper presents a new robust PID controller for automatic generation control (AGC) of hydro turbine power systems. The method is mainly based on a maximum peak resonance specification that is graphically supported by the Nichols chart. The open-loop frequency response curve is tangent to a specified ellipse and this makes the method to be efficient for controlling the overshoot, the stability and the dynamics of the system. Comparative results of this new load frequency controller with a conventional PI one and also with another PID controller design tested on a multimachine power system show the improvement in system damping remarkably. The region of acceptable performance of the new PID controller covers a wide range of operating and system conditions.

11/00832 A review of computer tools for analysing the integration of renewable energy into various energy systems

Connolly, D. *et al. Applied Energy*, 2010, 87, (4), 1059–1082.
This paper includes a review of the different computer tools that can be used to analyse the integration of renewable energy. Initially 68 tools were considered, but 37 were included in the final analysis which was carried out in collaboration with the tool developers or recommended points of contact. The results in this paper provide the information necessary to identify a suitable energy tool for analysing the integration of renewable energy into various energy-systems under different objectives. It is evident from this paper that there is no energy tool that addresses all issues related to integrating renewable energy, but instead the 'ideal' energy tool is highly dependent on the specific objectives that must be fulfiled. The typical applications for the 37 tools reviewed (from analysing single-building systems to national energy-systems), combined with numerous other factors such as the energy-

sectors considered, technologies accounted for, time parameters used, tool availability, and previous studies, will alter the perception of the 'ideal' energy tool. In conclusion, this paper provides the information necessary to direct the decision-maker towards a suitable energy tool for an analysis that must be completed.

11/00833 Assessment of cow dung as a supplementary fuel in a downdraft biomass gasifier

Roy, P. C. *et al. Renewable Energy*, 2010, 35, (2), 379–386.

A model of downdraft gasifier has been described considering thermodynamic equilibrium of species in the pyro-oxidation zone and kinetically controlled reduction reactions in the reduction zone. It is found that the sole use of cow dung as the gasifier fuel is not technically feasible. This is due to very low heating value of the producer gas with much carbon leaving the gasifier as char. However, cow dung can be used as a supplementary fuel blended with a conventional woody biomass, like sawdust. The increased fraction of cow dung in the fuel blend renders the gasification process less efficient, when the gasifier is operated at a particular equivalence ratio. Both the producer gas production rate and its heating value reduce with the increase in the cow dung content in the biomass fuel blend, leading to an overall reduction in the gasifier conversion efficiency. It is observed that an increase in the cow dung content from 0 to 90% in the blended fuel reduces the heating value by 46.8% and the conversion efficiency by 45%. The use of cow dung in between 40 and 50% by mass in the fuel mix would result in an overall fuel economy.

11/00834 Biofuels and their by-products: global economic and environmental implications

Taheripour, F. *et al. Biomass and Bioenergy*, 2010, 34, (3), 278–289.

Recently a number of papers have used general equilibrium models to study the economy-wide and environmental consequences of the first generation of biofuels (FGB). The authors argue that nearly all of these studies have overstated the impacts of FGB on global agricultural and land markets due to the fact that they have ignored the role of biofuel by-products. Feed by-products of FGB, such as dried distillers grains with solubles (DDGS) and oilseed meals (VOBP), are used in the livestock industry as protein and energy sources. Their presence mitigates the price impacts of biofuel production. More importantly, they reduce the demand for cropland and moderate the indirect land use consequences of FGB. This paper explicitly introduces DDGS and VOBP into a global computational general equilibrium (CGE) model, developed at the Center for Global Trade Analysis at Purdue University, to examine the economic and environmental impacts of regional and international mandate policies designed to stimulate bioenergy production and use. The authors show that models with and without by-products reveal different portraits of the economic impacts of the US and EU biofuel mandates for the world economy in 2015. While both models demonstrate significant changes in the agricultural production pattern across the world, the model with by-products shows smaller changes in the production of cereal grains and larger changes for oilseeds products in the US and EU, and the reverse for Brazil. Models that omit by-products are found to overstate cropland conversion from US and EU mandates by about 27%.

11/00835 Case study feasibility analysis of the Pelamis wave energy convertor in Ireland, Portugal and North America

Dalton, G. J. *et al. Renewable Energy*, 2010, 35, (2), 443–455.

The performance and economic viability of the Pelamis wave energy converter (WEC) has been investigated over a 20-year project time period using 2007 wave energy data from various global locations: Ireland, Portugal, USA and Canada. Previous reports assessing the Pelamis quote a disparate range of financial returns for the Pelamis, necessitating a comparative standardized assessment of wave energy economic indicators. An Excel model (NAVITAS) was created for this purpose which estimated the annual energy output of Pelamis for each location using wave height (H_s) and period (T_z) data, and produced financial results dependent on various input parameters. The economic indicators used for the analysis were cost of electricity (COE), net present value (NPV) and internal rate of return (IRR), modelled at a tariff rate of €0.20/kWh. Analysis of the wave energy data showed that the highest annual energy output (AEO) and capacity for the Pelamis was the Irish site, as expected. Portugal returned lower AOE similar to the lesser North American sites. Monthly energy output was highest in the winter, and was particularly evident in the Irish location. Moreover, the difference between the winter wave energy input and the Pelamis energy output for Ireland was also significant as indicated by the capture width, suggesting that Pelamis design was not efficiently capturing all the wave energy states present during that period. Modelling of COE for the various case study locations showed large variation in returns, depending on the number of WEC modelled and the initial cost input and learning curve. COE was highest when modelling single WEC in comparison to multiples, as well as when using 2004 initial costs in comparison to 2008 costs (at which time price of materials peaked). Ireland returned the lowest COE of €0.05/kWh modelling over 100 WEC at 2004 cost of materials, and €0.15/kWh at 2008 prices. Although favourable COE were recorded from some of the modelled scenarios, results indicated that NPV and IRR were not encouraging when using a €0.20/kWh tariff. It is recommended that a tariff rate of €0.30/kWh be considered for Ireland, and higher rates for other locations. In conclusion, Ireland had the most abundant wave energy output from the Pelamis. COE returns for Ireland were competitive for large number of WEC, even at peak costs, but it is recommended that careful analysis of NPV and IRR should be carried out for full economic assessment. Finally, a standardized method of COE reporting is recommended, using fixed WEC number or MW size, as well as standardized learning/production curves and initial costs, to facilitate confidence in investment decisions based on COE.

11/00836 Contested environmental policy infrastructure: socio-political acceptance of renewable energy, water, and waste facilities

Wolsink, M. *Environmental Impact Assessment Review*, 2010, 30, (5), 302–311.

The construction of new infrastructure is hotly contested. This paper presents a comparative study on three environmental policy domains in the Netherlands that all deal with legitimizing building and locating infrastructure facilities. Such infrastructure is usually declared essential to environmental policy and claimed to serve sustainability goals. They are considered to serve (proclaimed) public interests, while the adverse impact or risk that mainly concerns environmental values as well is concentrated at a smaller scale, for example in local communities. The social acceptance of environmental policy infrastructure is institutionally determined. The institutional capacity for learning in infrastructure decision-making processes in the following three domains is compared: (1) the implementation of wind power as a renewable energy innovation; (2) the policy on space–water adaptation, with its claim to implement a new style of management replacing the current practice of focusing on control and 'hard' infrastructure; (3) waste policy with a focus on sound waste management and disposal, claiming a preference for waste minimization (the 'waste management hierarchy'). All three cases show a large variety of social acceptance issues, where the appraisal of the impact of siting the facilities is confronted with the desirability of the policies. In dealing with environmental conflict, the environmental capacity of the Netherlands appears to be low. The policies are frequently hotly contested within the process of infrastructure decision-making. Decision-making on infrastructure is often framed as if consensus about the objectives of environmental policies exists. These claims are not justified, and therefore stimulating the emergence of environmental conflicts that discourage social acceptance of the policies. Authorities are frequently involved in planning infrastructure that conflicts with their officially proclaimed policy objectives. In these circumstances, they are often confronted with local actors who support alternatives that are in fact better in tune with the new policy paradigm.

11/00837 Development of future energy scenarios with intelligent algorithms: case of hydro in Turkey

Cinar, D. *et al. Energy*, 2010, 35, (4), 1724–1729.

Energy production is considered as one of the key indicators for economic development. It is vital to improve the renewable energy production for global sustainability, while leveraging the national resources. This study is contributing to the demonstration of using genetic algorithms (GA) in the development of future energy scenarios as well as to the strategic energy studies in Turkey. The forecasting model developed in this study uses forward feeding back-propagation (BP) method improved by GA. The proposed model is applied in the Turkish case. The test errors are shown to emphasize the positive difference between the proposed model and the classical BP model. The results highlight that there is strong evidence indicating that the government should reconsider their current energy strategies.

11/00838 Economic viability of the use of olive tree pruning as fuel for heating systems in public institutions in South Spain

Lopez, F. J. *et al. Fuel*, 2010, 89, (7), 1386–1391.

Biomass from olive tree pruning could be used as fuel for heating systems in boiler, thus helping to mitigate CO_2 emissions and reducing the dependence on fossil fuels. It also helps to reap secondary benefits, such as the creation of employment in rural areas. In the present study, an economic viability analysis about the use of olive tree pruning as fuel for heating systems in public schools of Lucena (Andalusia, Spain) have been carried out. This town has been selected due to its proximity to olive tree plantations. The heat cost calculations were based on the standard VDI 2067. Eventually, a sensitivity analysis to assess the effect of prices variation over the time needed to recover the investment has been carried out. It can be concluded that, in many cases, subsidies are needed to promote modern biomass technologies, to compensate for non-internalized external costs of fossil fuel systems. In case a subsidy

up to 50% of the investment is applied, payback is reduced, thus biomass boiler using olive tree chips is strongly recommended. Energy cost using olive tree chips is highly dependent on the high variability of the boilers working period. In all case studies, based on the sensitivity analysis, a maximum radius of 5 km of olive trees cuttings is enough to feed the public school boilers of the town. Also, it can be seen that the cost of energy considering either olive tree chips or olive pits is similar.

11/00839 From water to energy: the virtual water content and water footprint of biofuel consumption in Spain

Elena, G.-d.-C. and Esther, V. *Energy Policy*, 2010, 38, (3), 1345–1352.
Energy diversification and the use of renewable energy sources are key points in the European energy strategy. Biofuels are the most popular renewable resource option for the transport sector, and the European Union has established objectives that the Member States must adopt and implement. However, biofuel production at such a scale requires a considerable amount of water resources, and this water–energy nexus is rarely taken into account. This paper shows the strong nexus between water and energy in biofuel production and estimates the virtual water content and the water footprint from the raw material production that will be needed to reach the Spanish targets for biofuel consumption by 2010. The results show how the impact of such targets on the global and local water situation could be reduced through virtual water imports and, at the same time, how these imports could increase Spain's water and energy dependence. Hence, in order to manage water from an integral perspective of the territory, the inclusion of biofuel consumption objectives should go hand in hand with measures to reduce the demand of energy in the transport sector.

11/00840 How to proceed with competing alternative energy technologies: a real options analysis

Siddiqui, A. and Fleten, S. E. *Energy Economics*, 2010, 32, (4), 817–830.
Concerns about CO_2 emissions create incentives for the development and deployment of energy technologies that do not use fossil fuels. Indeed, such technologies would provide tangible benefits in terms of avoided fossil-fuel costs, which are likely to increase as restrictions on CO_2 emissions are imposed. However, a number of challenges need to be overcome prior to market deployment, and the commercialization of alternative energy technologies may require a staged approach given price and technical risk. The authors analysed how a firm may proceed with staged commercialization and deployment of competing alternative energy technologies. An unconventional new alternative technology is one possibility, where one could undertake cost-reducing production enhancement measures as an intermediate step prior to deployment. By contrast, the firm could choose to deploy a smaller-scale existing renewable energy technology, and, using the real options framework, the authors compared the two projects to provide managerial implications on how one might proceed.

11/00841 Hydraulic performance of an ancient Spanish watermill

Pujol, T. *et al. Renewable Energy*, 2010, 35, (2), 387–396.
The hydraulic performance of an ancient Spanish horizontal watermill is analysed in this paper. Previous studies of similar devices have focused on qualitative descriptions of their technical functioning, providing efficiency curves based on two-dimensional analytical approximations. In contrast, three-dimensional computational fluid dynamics (CFD) simulations are performed that obtain quantitative values for both the hydraulic torque and the power. The results found reveal how previous studies clearly overestimated the efficiency of these devices. Finally, use is made of the capabilities of CFD by investigating the performance of a modified blade profile. The proposed new design successfully increased the energy efficiency (up to 44%) in comparison with the classical one.

11/00842 Lake Sihwa tidal power plant project

Bae, Y. H. *et al. Ocean Engineering*, 2010, 37, (5–6), 454–463.
A tidal power plant is being constructed in the middle section of the existing Lake Sihwa dyke located near the southern Incheon Port in Korea. The project, which was due for completion in 2010, is to harness the largest tidal energy in the Kyeonggi Bay in the eastern Yellow Sea. While noting the current progress in terms of plant construction, this paper outlines the overall project in the tidal regime and uses predictive local flow modelling. The results of two-dimensional finite element method simulations that predict the real-time tidal characteristics during the construction and after the completion of the tidal power plant are presented, including a method to estimate the electricity output from the plant in the future.

11/00843 Long-term strategies for an efficient use of domestic biomass resources in Austria

Kalt, G. *et al. Biomass and Bioenergy*, 2010, 34, (4), 449–466.
In this study, long-term perspectives for the Austrian bioenergy sector are analysed. The focus is on the achievable contribution of biomass to the heat, electricity and transport fuel supply as well as to the total primary energy supply under different framework conditions. Also, the achievable greenhouse gas (GHG) mitigation and the costs related to GHG reduction are assessed. The analyses are based on scenarios which are compiled with the simulation model Green-$X_{Bio\text{-}Austria}$. Within this model a myopic optimization of the bioenergy sector with regard to energy generation costs up to 2050 in 11 scenarios is carried out. The scenarios differ in the following aspects: the projections for fuel price development and for the energy demand as well as bioenergy policy measures assumed. The major conclusions are: With respect to GHG emission reduction and economic efficiency, the simulations make clear that bioenergy policies should focus on the promotion of heat an – to some extent – combined heat and power generation. A focus on liquid biofuels for transport has adverse effects on the development of the bioenergy sector due to increased competition for limited biomass resources. For significantly increasing the share of biomass in the Austrian energy supply, it is crucial to both subsidize bioenergy and reduce the overall energy consumption. In the case of highly increasing fossil fuel prices, the economics of bioenergy systems will improve significantly.

11/00844 Microchannel reactor architecture enables greener processes

Lerou, J. J. *et al. Chemical Engineering Science*, 2010, 65, (1), 380–385.
Green chemistry is a design philosophy that aims to reduce or eliminate negative environmental impacts resulting from the production and use of chemicals. Microchannel process technology offers process intensification, in the form of enhanced heat and mass transfer, to a wide range of chemical reactions. This paper describes how the application of microchannel technology can help producers achieve the goals of green chemistry and minimize the environmental consequences of chemical and fuel production. The examples used to illustrate these advantages are Velocys' Fischer–Tropsch synthesis for biomass to liquids, DSM and Karlsruhe collaboration for fine chemical production, and Stevens Institute's work in applying microchannels to the production of hydrogen peroxide, as well as a detailed study of how microchannel architecture can minimize pollutant emissions from steam methane reforming.

11/00845 Negotiating river ecosystems: impact assessment and conflict mediation in the cases of hydro-power construction

Karjalainen, T. P. and Järvikoski, T. *Environmental Impact Assessment Review*, 2010, 30, (5), 319–327.
How the legitimacy of the impact assessment process is a key issue in conflict mediation in environmental impact assessment (EIA) is considered. Two EIA cases in hydro-power generation plans made for the Ii River, Finland in different decades are discussed, and how impact assessment in these cases has contributed to the creation, mediation and resolution of conflicts is evaluated. There is a focus on the elements of distributional and procedural justice that made the former EIA process more legitimate and consensual and the latter more conflictual. The results indicate that it is crucial for conflict mediation to include all the values and interests of the parties in the goal-setting process and in the definition and assessment of alternatives. The analysis also indicates that procedural justice is the most important to help the people and groups involved to accept the legitimacy of the impact assessment process: how different parties and their values and interests are recognized, and how participation and distribution of power are organized in an impact assessment process. It is confirmed in this article that SIA may act as a mediator or a forum providing a process through which competing knowledge claims, various values and interests can be discussed and linked to the proposed alternatives and interventions.

11/00846 Power potential of a split tidal channel

Atwater, J. F. and Lawrence, G. A. *Renewable Energy*, 2010, 35, (2), 329–332.
The extraction of kinetic energy from tidal flows is an interest of the renewable energy industry with large-scale assessments of the potential resource already conducted. These assessments however, use the natural kinetic energy flux as the primarily metric of the available resource. This approach has significant limitations when it is applied to tidal channels, particularly those tidal channels that branch into multiple sub-channels. Small amounts of energy extraction may not cause significant changes in the total flow through a channel, however the relative flows through the sub-channels can be drastically affected. It is this diversion of the flow that becomes the primary control on the extractable energy. As such, the relative resistance of the channels plays an important role.

11/00847 Study and design of a hybrid wind–diesel-compressed air energy storage system for remote areas

Ibrahim, H. *et al. Applied Energy*, 2010, 87, (5), 1749–1762.

Remote areas around the world predominantly rely on diesel-powered generators for their electricity supply, a relatively expensive and inefficient technology that is responsible for the emission of 1.2 million tons of greenhouse gas (GHG) annually, only in Canada. Wind–diesel hybrid systems (WDS) with various penetration rates have been experimented to reduce diesel consumption of the generators. After having experimented WDS that used various penetration rates, the authors considered how the re-engineering of existing diesel power plants could be achieved most efficiently, in terms of cost and diesel consumption, through the introduction of high penetration wind systems combined with compressed air energy storage. This study compares the available technical alternatives to supercharge the diesel that was used in this high penetration wind–diesel system with compressed air storage (WDCAS), in order to identify the one that optimizes its cost and performances. The technical characteristics and performances of the best candidate technology are subsequently assessed at different working regimes in order to evaluate the varying effects on the system. Finally, a specific WDCAS system with diesel engine downsizing is explored. This proposed design, that requires the repowering of existing facilities, leads to heightened diesel power output, increased engine lifetime and efficiency and to the reduction of fuel consumption and GHG emissions, in addition to savings on maintenance and replacement cost.

11/00848 Thirty years of domestic solar hot water systems use in Greece – energy and environmental benefits – future perspectives
Tsilingiridis, G. and Martinopoulos, G. *Renewable Energy*, 2010, 35, (2), 490–497.
The effort to reduce the dependence on imported crude oil in Greece, after the oil crises in the 1970s, has resulted, among others, in a total installed area of 3.57 million m^2 solar collectors in 2007, making Greece one of the pioneers in the use of domestic solar hot water system (DSHWS) worldwide. In the present work, the contribution of DSHWS to the reduction of conventional energy and greenhouse gases and other air pollutant emissions in Greece from its early years in mid-1970s up until now is assessed. DSHWS market penetration, solar system technological changes and development and demographic changes in association with the climatic conditions in all regions of the country have been taken into account in order to calculate energy conservation and emissions reduction. The results show that the conserved energy ranges from 21.27 GW h_{el} (0.1% of the domestic sector energy use) in 1978 to 1513 GW h_{el} (2.4%) in 2007, resulting in an abatement of CO_2 emissions, which for the year 2000 was 1.67 Mt, exceeding by 76% the objectives of the Greek program, 'Climatic Change', which indicated savings of 0.95 Mt CO_2 for 2000. Moreover DSHWS maximum technical potential is assessed to be about three times the current installed area, showing that they can play an important role in energy end environmental policy of the country.

14 FUEL SCIENCE AND TECHNOLOGY

Fundamental science, analysis, instrumentation

11/00849 3D study of cooling system effect on the heat transfer during polymer injection molding
Hassan, H. *et al. International Journal of Thermal Sciences*, 2010, 49, (1), 161–169.
The aim of the cooling system of a plastic injection mould is to provide thermal regulation in the injection moulding process. When the hot plastic melt enters the mould cavity, it cools down and solidifies by dissipating heat through the cooling system. To study the effect of the cooling system design on the solidification and heat transfer of polymer by injection moulding, a full three-dimensional time-dependent injection moulding numerical analysis is carried out. The configuration studied consists of the mould with cuboids-shape cavity having two different thicknesses. The cooling of the polymer material is carried out by cooling water flowing through horizontal six cooling channels. A numerical model by finite volume is used for the solution of the physical model. A validation of the numerical model is presented. The effect of the cooling channels position and their cross-section shape on the cooling process is carried out. The results indicate that, for the same cross-sectional area and coolant flow rate of the cooling channels, the cooling channels having the form rectangular perform the minimum time required to completely solidify the plastic product. They also indicate that when the cooling channels approach to the product surface, the cooling efficiency increases.

11/00850 A conceptual model for analyzing the stability condition and regime transition in bubble columns
Yang, N. *et al. Chemical Engineering Science*, 2010, 65, (1), 517–526.
The abrupt change on the curve of gas holdup versus superficial gas velocity calculated from the dual-bubble-size (DBS) model was physically interpreted as a shift from the homogeneous and transition regimes to the heterogeneous regime for bubble columns. The fundamentals related to the DBS model and this jump change are further analysed here. A conceptual analysis is performed on the momentum and energy transfer modes between phases and the partition of energy dissipation at different scales, thus the hydrodynamic equations can be closed with a stability condition formulated as a variational criterion, that is, the minimization of micro-scale energy dissipation or the maximization of meso-scale energy dissipation. Model calculation indicates that the stability condition drives the variation and evolution of structure parameters for the two bubble classes and hence causes the jump change of gas holdup which is due to the shift of the location of the global minimum point of the micro-scale energy dissipation from one ellipsoid of iso-surface to another in the three-dimensional space of structure parameters. The stability condition brings about the compromise between small and large bubbles in that these two classes compete with each other to approach a critical diameter at which drag coefficient reaches minimum. For different liquid media, generally only one bubble class could jump to the critical diameter, except the critical state at which the roles of stabilizing and destabilizing flow reach a balance and the two bubble classes jump together to the critical diameter. This may offer a physical explanation on the dual effect of liquid viscosity and surface tension on flow stability and regime transition reported in literature, and the model calculation for this dual effect and the regime map is in reasonable agreement with experimental findings.

11/00851 A mathematical model for transporting the biomass to biomass based power plant
Singh, J. *et al. Biomass and Bioenergy*, 2010, 34, (4), 483–488.
In Punjab, million of tons of agricultural biomass are being generated every year, but it is spatially scattered. The spatial distribution of this resource and the associated costs on collection and transportation are the major bottleneck in the success of biomass energy-conversion facilities. This paper deals with the mathematical model for collection and transporting the biomass from fields to biomass based power plant. The unit transport cost was calculated by using this model. Four systems of transport were conceptualized for two transport modes (tractor with wagon and truck). Three types of agricultural biomass (loose, baled and briquetted) were considered for transport analysis. For all modes of transport, it was observed that unit cost of transport decreases with increase in distance. The transport cost was least for briquetted biomass as compared to loose and baled biomass.

11/00852 A simple equation for temperature gradient in a planar SOFC stack
Kulikovsky, A. A. *International Journal of Hydrogen Energy*, 2010, 35, (1), 308–312.
The authors' recent model of heat transport in a planar SOFC stack is extended here to take into account finite hydrogen utilization. The extended model includes the heat balance equations in the interconnect and air flow, and the hydrogen mass balance equation in the anode channel. An approximate analytical expression for the gradient of stack temperature along the air channel is derived. The analytical result is in excellent agreement with the exact numerical solution. The resulting expression can be used for rapid estimate of the temperature gradient in a planar SOFC stack under real operating conditions.

11/00853 Adaptive HVAC zone modeling for sustainable buildings
Platt, G. *et al. Energy and Buildings*, 2010, 42, (4), 412–421.
Control of energy flows within a building is critical to achieving optimal performance of heating, ventilation and air-conditioning (HVAC) systems. To design optimal HVAC control strategies, a dynamic model of the HVAC system – particularly the building zones that it services – is essential. As analysis of building energy consumption is facilitated by the accurate prediction of indoor environmental conditions, techniques that dynamically model HVAC zones are crucial, and as such, is an active area of research. This paper focuses on real-time HVAC zone model fitting and prediction techniques based on physical principles, as well as the use of genetic algorithms for optimization. The proposed approach is validated by comparing real-time HVAC zone model fitting and prediction against the corresponding experimental measurements. In addition, comparison with prediction results using an

algorithm based on feedback-delayed Kalman filters has demonstrated the superiority of the proposed approach in terms of prediction accuracy.

11/00854 Analysis of fractal particles from diesel exhaust using a scanning-mobility particle sizer and laser-induced incandescence

Park, J. *et al. Journal of Aerosol Science*, 2010, 41, (6), 531–540.

The emission regulations for diesel particulate matter (PM) are becoming increasingly strict. The focus of regulations is turning to reducing the number of nanosized particles as well as the total mass. A more precise measurement technique for particle numbers and mass must be developed to meet these new regulations. In this study, a new method for estimating the mass weighted size distribution of diesel PM was investigated by measuring the size of primary particles and the number concentration distribution of particle aggregates. Time-resolved laser-induced incandescence was used for primary particle size measurement and a scanning-mobility particle sizer was used to quantify the number concentration of aggregates. The results from these two conventional measurement techniques were combined using fractal analysis formulas to relate the electrical mobility diameter, the number of primary particles per aggregate, primary particle size, and fractal dimension. This method, applied to single-cylinder diesel engine exhaust with various engine loads and injection pressures, successfully estimated the mass weighted size distribution of particle aggregates. The procedure is very simple and the estimations are comparable with those based on effective density, making this method a useful and reliable tool for estimating mass weighted size distribution of fractal particles such as diesel PM.

11/00855 Analysis of heat release dynamics in an internal combustion engine using multifractals and wavelets

Sen, A. K. *et al. Applied Energy*, 2010, 87, (5), 1736–1743.

This study analyses data from previously reported experimental measurements of cycle-to-cycle combustion variations in a lean-fuelled, multi-cylinder spark-ignition (SI) engine. The changes are characterized in the observed combustion dynamics with as-fed fuel–air ratio using conventional histograms and statistical moments, and the shifts further characterized in combustion complexity in terms of multifractals and wavelet decomposition. Changes in the conventional statistics and multifractal structure indicate trends with fuel–air ratio that parallel earlier reported observations. Wavelet decompositions reveal persistent, non-stochastic oscillation modes at higher fuel–air ratios that were not obvious in previous analyses. Recognition of these long-time-scale, non-stochastic oscillations is expected to be useful for improving modelling and control of engine combustion variations and multi-cylinder balancing.

11/00856 Application of a Bayesian model for the quantification of the European methodology for qualification of non-destructive testing

Gandossi, L. *et al. International Journal of Pressure Vessels and Piping*, 2010, 87, (2–3), 111–116.

The European methodology for qualification of non-destructive testing is a well-established approach adopted by nuclear utilities in many European countries. According to this methodology, qualification is based on a combination of technical justification and practical trials. The methodology is qualitative in nature, and it does not give explicit guidance on how the evidence from the technical justification and results from trials should be weighted. A Bayesian model for the quantification process was presented in a previous paper, proposing a way to combine the 'soft' evidence contained in a technical justification with the 'hard' evidence obtained from practical trials. This paper describes the results of a pilot study in which such a Bayesian model was applied to two realistic qualification dossiers by experienced non-destructive testing qualification specialists. At the end of the study, recommendations were made and a set of guidelines was developed for the application of the Bayesian model.

11/00857 Comparison of electrical and laser spark emission spectroscopy for fuel concentration measurements

Letty, C. *et al. Experimental Thermal and Fluid Science*, 2010, 34, (3), 338–345.

Emission spectra from electrical and laser sparks in flowing methane–air mixtures of various compositions have been collected and analysed. The differences and similarities between the electrical and laser sparks in the context of their emission are discussed. The emission spectra from the laser spark were characterized by a weak continuum, onto which several strong atomic lines and some molecular bands were superimposed, in contrast to the spectra of electrical spark which had a strong continuum, few atomic lines and several strong molecular bands were evident, thus making laser spark spectroscopy a more accurate technique to measure hydrocarbon concentration. For both types of spark, the total intensity of the CN chemiluminescence around 388 nm was found to correlate almost linearly with fuel concentration in methane–air mixtures.

11/00858 Development of probabilistic fracture mechanics analysis codes for reactor pressure vessels and piping considering welding residual stress

Onizawa, K. *et al. International Journal of Pressure Vessels and Piping*, 2010, 87, (1), 2–10.

Probabilistic fracture mechanics (PFM) analysis codes for reactor pressure vessels (RPVs) and piping, called as PASCAL (PFM Analysis of Structural Components in Aging LWRs) series, have been developed. The PASCAL2 (PASCAL version 2) evaluates the conditional probability of fracture of an RPV under transient conditions including pressurized thermal shock (PTS) considering neutron irradiation embrittlement of the vessels. Recent improvements to PASCAL2 are related to the treatment of weld–overlay cladding. The results using the improved code indicate that the residual stress by weld–overlay cladding affects the fracture probability to some extent. The PASCAL-SP (PASCAL – Stress corrosion cracking at welding joints for Piping) evaluates the probabilities of failures including leakage and breaks of safety-related piping complying with Japanese regulation and rules. Effects of welding residual stress distribution as well as inspection accuracy are focused in this study. Residual stress distributions have been determined by parametric FEM analyses and incorporated into the code.

11/00859 Dynamic simulation of Ledinegg instability

Ruspini, L. C. *et al. Journal of Natural Gas Science and Engineering*, 2010, 2, (5), 211–216.

Ledinegg flow excursion could produce severe damage in thermal-hydraulic components due to fast changes in the main thermodynamic variables. In this work, this phenomenon is studied by simulating the transient behaviour of the system during these excursive transitions. How the dynamic delays modify the pressure drop versus flow characteristic curve is also considered. Numerical aspects related to the application of an adaptive high-order method to the resolution of these complex thermal-hydraulic problems are discussed.

11/00860 Effects of temperature dependent thermal conductivity on Nu number behavior in micro-tubes

Lelea, D. *International Communications in Heat and Mass Transfer*, 2010, 37, (3), 245–249.

The numerical modelling of the conjugate heat transfer and fluid flow through the micro-tube is presented in the paper. Three different fluids with temperature-dependent fluid properties were considered: water and two dielectric fluids, HFE-7600 and FC-70. The diameter ratio of the micro-tube was $D_i/D_o = 0.1/03$ mm with a tube length $L = 70$ mm. The laminar fluid flow regime was analysed. Two different heat transfer conditions were considered: heating and cooling. The influence of the temperature-dependent thermal conductivity on Nu number was analysed for these two cases and compared with k = const.

11/00861 Estimation of uncertainty with the modulus of elasticity measured by means of tensile test for BSCCO tapes

Osamura, K. *et al. Cryogenics*, 2010, 50, (10), 660–665.

The international round robin test (RRT) was conducted in order to establish the international standard for the tensile test method for BSCCO-2223 tape-shaped wires. The mechanical properties were statistically analysed to estimate their standard uncertainties and their correlation among laboratories. Consequently, a large variance was observed with the modulus of elasticity determined from the initial loading curve. The reason has been examined by estimating type B uncertainties at every step of the experimental procedure. With respect to the modulus of elasticity, the average of relative standard uncertainty (RSU) obtained from the RRT coincided roughly with that derived by means of type B evaluation. Thus, it is concluded that the type B evaluation is very effective tool for predicting the uncertainties of observations such as modulus of elasticity. On the other hand, the grand overall RSU was larger than the grand intra-lab one. The combined standard uncertainties were calculated by changing the strain rate, but with other parameters kept constant. In order to suppress the influence from the strain rate to the variance, it was recommended that the strain rate should be regulated less than 2×10^{-4} 1/s in the tensile test method.

11/00862 Exploring the effect of fluid dynamics and kinetic mechanisms on *n*-heptane autoignition in transient jets

Viggiano, A. *Combustion and Flame*, 2010, 157, (2), 328–340.

The influence of physical parameters and of flow patterns on the prediction of *n*-heptane ignition dynamic in transient reacting *n*-heptane jets, in high pressure environment under laminar conditions, has been explored by using different kinetic mechanisms. Some preliminary transient laminar flamelet computations have been

performed, thus showing that the sensitivity of the ignition time to strain rate depends on the kinetic mechanism used. Therefore, the structure of the reacting jet, in particular the localization of ignition spots, is investigated. The results show that, if the initial temperature of the reacting mixture is out of the intermediate range (800–1000 K) towards lower values, the fluid dynamics has an essential role. In this case, the ignition delay time is almost insensitive to the specific kinetic mechanism adopted, conversely it is severely shortened by increasing the streamwise velocity. The burning spot is located in the core of fuel roll-up, where low values of scalar dissipation rate occur. Nevertheless, the most reactive mixture fraction conditions are well predicted by chemical kinetics, as they are in good agreement with those computed for the one-dimensional diffusion layer. When the initial temperature of fuel and air is increased in the intermediate range, ignition is strongly dependent on the kinetic mechanism used. In these cases, the choice of an accurate chemical scheme is fundamental in order to obtain reliable results.

11/00863 Frequency-modulated hyperbolic heat transport and effective thermal properties in layered systems

Ordóñez-Miranda, J. and Alvarado-Gil, J. J. *International Journal of Thermal Sciences*, 2010, 49, (1), 209–217.

In this work heat transport in layered systems is analysed using a hyperbolic heat conduction equation and considering a modulated heat source for both Dirichlet and Neumann boundary conditions. In the thermally thin case, with Dirichlet boundary condition, the well known effective thermal resistance formula is derived; while for Neumann problem only a heat capacity identity is found, due to the fact that in this case this boundary condition cannot become asymptotically steady when modulation frequency goes to zero. In contrast in the thermally thick regime, heat transport shows a strong enhancement when hyperbolic effects are considered. For this thermal regime, an analytical expression, for both Dirichlet and Neumann conditions, is obtained for the effective thermal diffusivity of the whole system in terms of the thermal properties of the individual layers. It is shown that the magnifying effects on the effective thermal diffusivity are especially remarkable when the thermalization time and the thermal relaxation time are comparable. The limits of applicability of the equation, in the thermally thick regime are shown to provide useful and simple results in the characterization of layered systems. Enhancement in thermal transport and in the effective thermal diffusivity is a direct consequence of having taken into account the fundamental role of the thermal relaxation time in addition to the thermal diffusivity and thermal effusivity of the composing layers. It is shown that the results can be reduced to the ones obtained using Fourier heat diffusion equation, when the thermal relaxation times tend to zero.

11/00864 Ice slurry production using supercooling phenomenon

Bédécarrats, J.-P. *et al. International Journal of Refrigeration*, 2010, 33, (1), 196–204.

The studied ice slurry production consists in generating ice from a flow of supercooled water or aqueous solution. After leaving the evaporator of the refrigerating plant, the supercooled flow is physically disturbed in order to generate ice crystals. The influence of different parameters on the crystallization have been studied: the level of supercooling, the flow rate and the refrigerant temperature. The results have shown the difficulty to control a plant where the supercooling phenomenon is undergoing. The stochastic character of the crystallization interferes with the reproducibility of the results. However, the experiments showed that it is possible to find operating parameters with enough safety margin to avoid the crystallization inside the tube of the exchanger. A modelling of the evaporator was carried out in order to apprehend the physical phenomena and the risks of crystallization within the evaporator.

11/00865 Influence of ultrasonic conditioning of flocculant on the aggregation process in a tank with turbine mixer

Lemanowicz, M. *et al. Chemical Engineering and Processing: Process Intensification*, 2010, 49, (2), 205–211.

Aggregation is a very widely encountered phenomenon in nature as well as in industrial processes. It plays an important role in processing of air and water, e.g. wastewater treatment plants, power plants, mining facilities. The new, cost-effective solutions are developed. Among the others modification of the flocculants by means of ultrasound, mixtures with surfactants or polydispersive flocculant blends can be mentioned. Flocculants used in the aggregation process are long-chain polymers that can be of negative, positive or neutral charge. The aggregation caused by usage of such flocculants is the result of three different mechanisms: bridging, charge neutralization or electrostatic patch. The influence of ultrasonic field on the efficiency of different flocculants was investigated. Suspension of chalk in water was used and the measurements were taken in the laser particle sizer. The influence of the sonication time on flow curves is also presented.

11/00866 Mathematical modelling of ethanol production by mixed kefir grains yeast population as a function of temperature variations

Zajšek, K. and Goršek, A. *Biochemical Engineering Journal*, 2010, 49, (1), 7–12.

A mathematical model was developed to describe the effect of temperature and fermentation time on the kinetic parameters of ethanol production by the mixed kefir grains yeast population, using full fat cow's milk as a fermentation medium. A modified Gompertz model was used to describe this phenomenon. The kinetic parameters of the model were successfully predicted by using the least-squares method. The influence of temperature on kefir grains biomass increase and microbiological composition of kefir product and kefir grains was investigated and quantified. Furthermore, an Arrhenius relationship between operating temperature and the maximum ethanol production rate was established. The activation energy of ethanol production was 64.3 kJ/mol. The adopted mathematical model could be used to describe the dynamics of ethanol production from the beginning up to the stationary phase during the kefir fermentation.

11/00867 Performance of superconducting nanowire single photon detection system with different temperature variation

Shen, X. F. *et al. Cryogenics*, 2010, 50, (10), 708–710.

The performance of a cryocooler-based superconducting single photon detection system suffers from the intrinsic temperature oscillation, which is typically approximately 300 mK around 4.2 K originated from the periodic expansion of the cryocooler's working fluid (He). By using a rare-earth alloy (ErNi) plate with a high heat capacity at cryogenic temperatures in between the cold head of the cryocooler and the detector block, the detector temperature variation is successfully damped to be less than 10 mK. The dark count rate is reduced and the maximum working bias current is increased. The quantum efficiency of the SNSPD system is significantly improved by 40%.

11/00868 Quantification of oxygen surface groups on carbon materials via diffuse reflectance FT-IR spectroscopy and temperature programmed desorption

Kohl, S. *et al. Catalysis Today*, 2010, 150, (1–2), 67–70.

The aim of this investigation was to quantify surface oxygen groups on an activated carbon by combining the results from temperature programmed desorption (TPD) and diffuse reflectance FT-IR spectroscopy (DRIFTS). A commercial activated carbon was oxidized with ozone to form surface oxygen groups. Afterwards the samples were heated in TPD experiments up to 500 °C. The evolved gases were detected and quantified via IR spectroscopy and DRIFT spectra were collected from the heat-treated samples. Simulation of the DRIFT spectra with a set of Gauss functions led to identification of four surface oxygen groups in the range of 1500–1950 cm^{-1}. Specific concentrations of the four groups can be calculated with the conversion factors obtained by combining TPD and DRIFTS information.

11/00869 Reflectance spectroscopy is an effective tool for monitoring soot pollution in an urban suburb

Saaroni, H. *et al. Science of The Total Environment*, 2010, 408, (5), 1102–1110.

This study examines whether converting the fossil fuel of the Tel Aviv power station from oil to gas influences air pollution in the local urban environment. To this end, the spectral properties of accumulated dust on tree leaves and paper bags were assessed before (2004) and after (2006) the conversion. The sampling site was a garden in a neighbourhood located 2700 m downwind of the power station. In addition, air pollution concentrations and particulate matter parameters recorded by a local meteorological station were analysed (PM_{10}, NO_x, NO_2, NO, and SO_2). Although differences in the average monthly concentration of pollution parameters are mostly insignificant between the two periods, the accumulated particulate matter exhibits considerably different spectral patterns. All first period samples exhibit a distinctly concave slope in the spectral region between 400 and 1400 nm, indicative of high amounts of soot, most likely due to the combustion products of fuel oil exhausted by the power plant. In contrast, the second period samples exhibit spectra that indicate reduced soot content and even appear slightly convex, evidencing the presence of dust of mineral origin, a feature likely masked by the soot in the first period. Thus, the spectral data support that the power plant conversion results in less pollution. More generally, this study corroborates that VIS-NIR-SWIR spectroscopy characterizes key properties of the particulate layer accumulating on sampled surfaces and thus, is a powerful method for monitoring the urban environment.

11/00870 Refrigerant concentration measurement at compressor oil sump by refractive index (concentration of R410A in PVE oil)

Fukuta, M. *et al. International Journal of Refrigeration*, 2010, 33, (2), 390–397.

The dissolution of refrigerant into refrigeration oil has great influence on oil viscosity. In this study, a refractive index measurement is applied to measure the refrigerant concentration in the oil at a compressor oil sump. Although the refractive index of the oil/refrigerant mixture is correlated with the refrigerant concentration using the refractive indices of the oil and the refrigerant, the temperature of the oil in the compressor is so high that the refractive index of the refrigerant cannot be defined because the temperature surpasses the critical temperature of the refrigerant. Therefore the correlation under such high temperature conditions is examined. It is found to be reasonable to use the refractive index of the refrigerant derived by an extrapolation of the refractive indices of the saturated liquid refrigerant under a sub-critical condition. In addition, a transient measurement of the refrigerant concentration in the oil was carried out in a practically operated compressor. Although the output signal of the sensor is disturbed by bubbles generated during the separation of the refrigerant from the oil, a data processing procedure which eliminates the over-ranged signal and averages the output within a certain time period is proposed for eliminating the influence of the bubbles.

11/00871 Revision, calibration, and application of the volume method to evaluate the geothermal potential of some recent volcanic areas of Latium, Italy

Doveri, M. *et al. Geothermics*, 2010, 39, (3), 260–269.

The volume method is used to evaluate the productive potential of unexploited and minimally exploited geothermal fields. The distribution of P_{CO2} in shallow groundwaters delimits the geothermal fields. This approach is substantiated by the good correspondence between zones of high CO_2 flux, and the areal extension of explored geothermal systems of high enthalpy (Monte Amiata and Latera), medium enthalpy (Torre Alfina) and low enthalpy (Viterbo). Based on the data available for geothermal fields either under exploitation or investigated by long-term production tests, a specific productivity of $40\,t\,h^{-1}\,km^{-3}$ is assumed. The total potential productivity for the recent volcanic areas of Latium is about $28 \times 10^3\,t\,h^{-1}$, with 75% from low-enthalpy geothermal fields, 17% from medium-enthalpy systems, and 8% from high-enthalpy reservoirs. The total extractable thermal power is estimated to be 2220–2920 MW, 49–53% from low-enthalpy geothermal fields, 28–32% from medium-enthalpy systems, and 19–20% from high-enthalpy reservoirs.

11/00872 Solution of a Cattaneo-Maxwell diffusion model using a spectral element least-squares method

Carella, A. R. and Dorao, C. A. *Journal of Natural Gas Science and Engineering*, 2010, 2, (5), 253–258.

Fluidized bed reactors are widely used in gas processing facilities due to their superior heat and mass transfer characteristics. Reaction rates in these reactors depend on the diffusion of species into the catalytic particles. A more accurate description of diffusion than Fick's law provides is required for the optimization of the design of these reactors. In this work, a least squares finite element framework was implemented in order to solve the evolution of the concentration profile predicted by Cattaneo-Maxwell's law inside a catalytic pellet. Fick's and Cattaneo-Maxwell's models were compared, being the obtained predictions significantly different for time scales similar to the relaxation time but converging asymptotically for larger time scales. Time-marching and full-domain numerical approaches were compared. The convenience of the time-marching approach was verified, since this approach yields the same accuracy with less computational cost.

11/00873 Study of scraping force of ice growing on cooling solid surface

Matsumoto, K. *et al. International Journal of Refrigeration*, 2010, 33, (2), 419–427.

In a dynamic ice storage system, one of typical methods to form ice slurry is a 'Harvest method' where ice growing on the cooling surface is scraped by a rotary knife. This method has an advantage that ice adhesion to a cooling wall, which is a serious problem in a conventional method, is not necessary to be considered. In this study, ice was formed on a carbon steel surface by cooling an ethylene-glycol solution with stirring, and ice growing on the cooling surface was scraped. At that time, scraping force was measured, varying supercooling degrees of the solution, ice formation times, concentrations of the solution and surface temperatures and surface roughness of the carbon steel. And, influences of the above parameters on scraping force were clarified, and behaviours of ice scraped from the carbon steel surface were classified. Moreover, ice growing on the surface was continuously scraped repeatedly. At that time, influence of the number of scrapings on scraping force was clarified.

11/00874 Study on specific enthalpy of ice including solute in aqueous solution

Kumano, H. *et al. International Journal of Refrigeration*, 2010, 33, (3), 480–486.

Effects of solute included in a sample on the specific enthalpy of ice are investigated experimentally. In the experiments, ice including the solute was made from an aqueous solution, and the specific enthalpy was measured by melting the ice in the aqueous solution. Moreover, a physical model of the ice including the solute is proposed. As a result, when the concentration of the aqueous solution is set at a value equivalent to the concentration of the sample, the specific enthalpy of the sample increases with the concentration of the sample. The measurement results and the calculated values agree well, and it was found that the method for calculating the specific enthalpy of the sample is valid. Moreover, when the concentration of the aqueous solution is higher than that of the ice including the solute, it was found the calculation method for the specific enthalpy of the sample is appropriate.

11/00875 Temperature-explicit formulation of energy equation for thermal–hydraulic analyses

Kim, J. *et al. International Communications in Heat and Mass Transfer*, 2010, 37, (3), 256–260.

A temperature equation, which is derived from an enthalpy transport equation by using an assumption of a constant specific heat, is very attractive for analyses of heat and fluid flows. It can be used for an analysis of a solid–fluid conjugate heat transfer, and it does not need a numerical method to obtain temperature from a temperature–enthalpy relation. But its application is limited because of the assumption. A new method is derived in this study, which is a temperature-explicit formulation of the energy equation. The enthalpy form of the energy equation is used in the method. But the final discrete form of the equation is expressed with temperature. The discretized equation from the temperature-explicit formulation can be used for a heat transfer analysis in a solid–fluid coupled region without any special treatment at the solid–fluid interface. And it can be applied for multiphase flows with a real gas effect. It is found by numerical tests in this study that the proposed method is very efficient and as accurate as the standard enthalpy formulation.

11/00876 Thermoeconomic analysis method for optimization of insulation thickness for the four different climatic regions of Turkey

Ucar, A. *Energy*, 2010, 35, (4), 1854–1864.

Thermal insulation is one of the most effective energy-conservation measures in buildings. For this reason, the energy savings can be obtained by using proper thickness of insulation in buildings. In this study, the optimum thickness of insulation considering condensed vapour in external walls are found by using exergoeconomic analysis. The four various cities from four climate zones of Turkey, namely, Antalya, İstanbul, Elaziğ and Erzurum are selected for the analysis. The optimum insulation thickness for Antalya, İstanbul, Elaziğ and Erzurum are obtained as 0.038, 0.046, 0.057 and 0.0739 m at indoor temperature of 20 °C, respectively. The results show that the optimum insulation thickness at the indoor temperature of 18 and 22 °C are determined as 0.0663 and 0.0816 m for the city of Erzurum, respectively. The energy saving for the city of Erzurum is found as 77.2% for the indoor temperature of 18 °C, 79.0% for the indoor temperature of 20 °C and 80.6% for the indoor temperature of 22 °C, when the optimum insulation is applied.

11/00877 Three dimensional numerical investigation of air flow over domed roofs

Faghih, A. K. and Bahadori, M. N. *Journal of Wind Engineering and Industrial Aerodynamics*, 2010, 98, (3), 161–168.

Domed roofs have been used in Iran and many other countries to cover large buildings such as mosques, shrines, churches, schools, etc. However, their favourable thermal performance has enabled them to be used for other buildings such as bazaars or market places in Iran. The aim of this study was to determine the air pressure distribution over domed roofs, employing a numerical method. In this investigation a three-dimensional model and a laminar inlet air flow were considered. The k–ε RNG method was employed for the turbulent flow simulation method. Simulation was run under three conditions of windows and a hole on top of the dome being open, or closed. The results were compared with the results obtained by an experimental investigation of the same domed-roof model. The results of this research can be used to determine the heat transfer coefficient of wind blowing on domed roofs and the passive cooling effect of such structures.

11/00878 Three-dimensional multi-scale plate assembly for maximum heat transfer rate density

Bello-Ochende, T. *et al. International Journal of Heat and Mass Transfer*, 2010, 53, (4), 586–593.

This paper extends the design concept for generating multi-scale structures in forced convection for a finite-size flow system to a three-dimensional heat-generating plate with the objectives of maximizing heat transfer rate density, or the heat transfer rate per unit volume.

The heat-generating plates, arranged in a stack form channels in which the fluids are forced through by an applied pressure difference. The first stage of this work consists of numerical simulation of the flow and heat transfer in a large number of flow configurations, to determine the optimum plate spacing, and the maximum heat transfer rate density. In the subsequent stages, shorter plates are inserted in the centres at adjacent (longer) plates in the entranced region were the boundary layer are thin and there is a core of unused fluid. The heat transfer density is further increased by progressively inserting another set of even shorter plates between the plates and then optimizing the whole structure. The resulting structure is an optimized multi-scale and multi-channel structure with horizontal equidistant heated plates of decreasing lengths scales. Further more the effects of plate thickness and dimensionless pressure drop number on the multi-scale structure was investigated. The numerical results are found to be in good agreement with predicted analytical results.

11/00879 Time series models (Grey-Markov, Grey Model with rolling mechanism and singular spectrum analysis) to forecast energy consumption in India
Kumar, U. and Jain, V. K. *Energy*, 2010, 35, (4), 1709–1716.
The present study applies three time series models, namely, Grey-Markov model, Grey-Model with rolling mechanism, and singular spectrum analysis (SSA) to forecast the consumption of conventional energy in India. Grey-Markov model has been employed to forecast crude-petroleum consumption while Grey-Model with rolling mechanism to forecast coal, electricity (in utilities) consumption and SSA to predict natural gas consumption. The models for each time series has been selected by carefully examining the structure of the individual time series. The mean absolute percentage errors for two out of sample forecasts have been obtained as follows: 1.6% for crude-petroleum, 3.5% for coal, 3.4% for electricity and 3.4% for natural gas consumption. For two out of sample forecasts, the prediction accuracy for coal consumption was 97.9%, 95.4% while for electricity consumption the prediction accuracy was 96.9%, 95.1%. Similarly, the prediction accuracy for crude-petroleum consumption was found to be 99.2%, 97.6% while for natural gas consumption these values were 98.6%, 94.5%. The results obtained have also been compared with those of Planning Commission of India's projection. The comparison clearly points to the enormous potential that these time series models possess in energy consumption forecasting and can be considered as a viable alternative.

11/00880 Transient and steady-state forced convection to power-law fluids in the thermal entrance region of circular ducts: effects of viscous dissipation, variable viscosity, and axial conduction
Dehkordi, A. M. and Memari, M. *Energy Conversion and Management*, 2010, 51, (5), 1065–1074.
A numerical study was conducted on the transient behaviour of a hydrodynamically fully developed, laminar flow of power-law fluids in the thermally developing entrance region of circular ducts with taking into account the effects of viscous dissipation, axial conduction, and variations of viscosity with temperature. In this regard, the unsteady-state thermal energy and momentum equations were solved numerically using a finite-difference method, whereas the steady-state thermal energy equation with constant wall heat flux as the boundary condition was solved analytically as the initial condition of the former. The numerical procedure used in the present work was validated with an analytical solution for the special case of Newtonian fluids. The effects of the power-law index, axial conduction, wall heat flux, and variations of fluid viscosity on the local Nusselt number and thermal entrance length were investigated. Moreover, the local Nusselt number values of steady-state conditions were correlated as a function of the power-law index and wall heat flux. Furthermore, a correlation was derived for the thermal entrance length as a function of the power-law index and wall heat flux.

11/00881 Validation of a novel fiber optic strain gauge in a cryogenic and high magnetic field environment
Baxter, S. *et al. Cryogenics*, 2010, 50, (10), 700–707.
This paper reports on the first operation of an easy-to-use low-cost novel fibre optic strain gauge (FOSG) in cryogenic and magnetic field environments. The FOSGs were mounted on a superconducting coil and resin impregnated. The gauges detected resin shrinkage on curing. On cooldown, the FOSG monitored the thermal contraction strains of the coil and the electromagnetic strain during energization. The coil was deliberately quenched, in excess of 175 times, and again the FOSG detected the quenches and measured the thermal expansion-induced strains and subsequent re-cooling of the coil after a quench. Agreement with finite element analysis predictions was very good.

Fuel cell technology

11/00882 Analysis of a proton-conducting SOFC with direct internal reforming
Arpornwichanop, A. *et al. Chemical Engineering Science*, 2010, 65, (1), 581–589.
This paper presents a performance analysis of a planar solid oxide fuel cell (SOFC) with proton-conducting electrolyte (SOFC-H^+). The SOFC-H^+ is fuelled by methane and operated under direct internal reforming and isothermal conditions. A one-dimensional steady-state model coupled with a detailed electrochemical model is employed to investigate the distribution of gas composition within fuel and air channels and all the electrochemical-related variables. The current–voltage characteristics of SOFC-H^+ are analysed and the result shows that the operation of SOFC-H^+ at 0.7 V gives a good compromise on power density and fuel utilization. However, high CO content at fuel channel is observed at this condition and this may hinder the SOFC-H^+ performance by reducing catalyst activity. The effect of key cell operating parameters, i.e. steam to carbon ratio, temperature, pressure, and water content in oxidant, on the performance of SOFC-H^+ and the content of CO is also presented in this study.

11/00883 Control of hybrid fuel cell/energy storage distributed generation system against voltage sag
Hajizadeh, A. and Aliakbar Golkar, M. *International Journal of Electrical Power & Energy Systems*, 2010, 32, (5), 488–497.
Fuel cell and energy storage based hybrid distributed power generation systems appear to be very promising for satisfying high energy and high power requirements of power quality problems in distributed generation systems. In this study, design of control strategy for hybrid fuel cell/energy storage distributed power generation system during voltage sag has been presented. The proposed control strategy allows hybrid distributed generation system works properly when a voltage disturbance occurs in distribution system and hybrid system stays connected to the main grid. Hence, modelling, controller design, and simulation study of a hybrid distributed generation system are investigated. The physical model of the fuel cell stack, energy storage and the models of power conditioning units are described. Then the control design methodology for each component of the hybrid system is proposed. Simulation results are given to show the overall system performance including active power control and voltage sag ride-through capability of the hybrid distributed generation system.

11/00884 CO_2 capture from combined cycles integrated with molten carbonate fuel cells
Campanari, S. *et al. International Journal of Greenhouse Gas Control*, 2010, 4, (3), 441–451.
In this paper molten carbonate fuel cells (MCFCs) are considered for their potential application in carbon dioxide separation when integrated into natural gas fired combined cycles. The MCFC performs on the anode side an electrochemical oxidation of natural gas by means of CO_3^{2-} ions which, as far as carbon capture is concerned, results in a twofold advantage: the cell removes CO_2 fed at the cathode to promote carbonate ion transport across the electrolyte and any dilution of the oxidized products is avoided. The MCFC can be 'retrofitted' into a combined cycle, giving the opportunity to remove most of the CO_2 contained in the gas turbine exhaust gases before they enter the heat recovery steam generator (HRSG), and allowing to exploit the heat recovery steam cycle in an efficient 'hybrid' fuel cell + steam turbine configuration. The carbon dioxide can be easily recovered from the cell anode exhaust after combustion with pure oxygen (supplied by an air separation unit) of the residual fuel, cooling of the combustion products in the HRSG and water separation. The resulting power cycle has the potential to keep the overall cycle electrical efficiency approximately unchanged with respect to the original combined cycle, while separating 80% of the CO_2 otherwise vented and limiting the size of the fuel cell, which contributes to about 17% of the total power output so that most of the power capacity relies on conventional low cost turbo-machinery. The calculated specific energy for CO_2 avoided is about four times lower than average values for conventional post-combustion capture technology. A sensitivity analysis shows that positive results hold also changing significantly a number of MCFC and plant design parameters.

11/00885 Effects of the cell thermal behavior and water phase change on a proton exchange membrane fuel cell performance
Afshari, E. and Jazayeri, S. A. *Energy Conversion and Management*, 2010, 51, (4), 655–662.
A two-dimensional, non-isothermal, electrochemical-transport using a fully coupled numerical model is developed for a proton exchange membrane fuel cell to investigate simultaneous water, heat transport phenomena and their effects on cell performance. The multiphase

mixture formulation for the two-phase transport process is used, and developed model is treated as a single domain. This process is leading to a single set of conservation equations consisting of continuity, momentum, species, potential and energy for all regions of cell. The result indicates that flooding of porous cathode reduces the rate of oxygen transport to the cathode catalyst layer and causes an increase in cathode polarization. Also, flooding could effect current density distribution, where a slight abrupt change occurs in the slope of the local current density curve. The amount and location of condensation in the GDL cathode is directly related to the cell temperature, where the temperature difference predicted by this model is about 3.7 °C at 0.6 V. The maximum temperature occurs near the inlet and at interface between membrane/catalyst layers at cathode side where major heat generation takes place. The results are validated with experimental data available that are in good agreement.

11/00886 Electrochemical hydrogen separation and compression using polybenzimidazole (PBI) fuel cell technology

Thomassen, M. *et al. Journal of Natural Gas Science and Engineering*, 2010, 2, (5), 229–234.

Simultaneous hydrogen separation and compression using high-temperature (>100 °C) polymer electrolyte membrane (PEM) fuel cell technology (PBI) was demonstrated for pure hydrogen, nitrogen/hydrogen mixtures and reformate feed gas mixtures containing various amounts of CO, CO_2 and CH_4. Gas purity measurements of the separated gas were performed and significant reductions in impurities were achieved. The effects of hydrogen concentration, inlet gas humidification, operating temperature and air bleed on the cell performance were studied and hydrogen diffusion through the polybenzimidazole membrane was measured. The hydrogen separation required relatively low energy consumption and demonstrated good dynamic response. Simultaneous separation and compression of hydrogen up to 0.65 bar was demonstrated.

11/00887 Experimental investigation of dynamic performance and transient responses of a kW-class PEM fuel cell stack under various load changes

Tang, Y. *et al. Applied Energy*, 2010, 87, (4), 1410–1417.

The dynamic performance is a very important evaluation index of proton exchange membrane (PEM) fuel cells used for real application, which is mostly related with water, heat and gas management. A commercial PEM fuel cell system of Nexa module is employed to experimentally investigate the dynamic behaviour and transient response of a PEM fuel cell stack and reveal involved influential factors. Five groups of dynamic tests are conducted and divided into different stage such as start-up, shut-down, step-up load, regular load variation and irregular load variation. It is observed that the external load changes the current output proportionally and reverses stack voltage accordingly. The purge operation benefits performance recovery and enhancement during a constant load and its time strongly depends on the operational current level. Overshoot and undershoot behaviours are observed during transience. But the current undershoot does not appear due to charge double-layer effect. Additionally, magnitudes of the peaks of the voltage overshoot and undershoot vary at different current levels. The operating temperature responds fast to current load but changes slowly showing an arc-like profile without any overshoot and undershoot events. The air flow rate changes directly following the dynamic load demand. But the increased amount of air flow rate during different step-change is not identical, which depends on the requirement of internal reaction and flooding intensity. The results can be utilized for validation of dynamic fuel cell models, and regarded as reference for effective control and management strategies.

11/00888 Experiments of a 20 cell PEFC operating under fault conditions with diode by-pass circuit for uninterrupted power delivery

De Bernardinis, A. *et al. Energy Conversion and Management*, 2010, 51, (5), 1044–1054.

The work presents the results of experiments related to the electrical and dynamical behaviour of a 500 W, 20 cell polymer electrolyte fuel cell (PEFC) stack operated under fault condition and connected to an anti-parallel diode acting as a by-pass. The stack is placed in an experimental set-up that reproduces the electrical coupling in series of two fuel cells. The results allow the evaluation of the bypass diode solution in the case of specific degraded working modes such as the break of the gas reactant feeding. The experiments presented in this article constitute an extrapolation and a complementary investigation of the preliminary results already achieved on a two cell PEFC stack and which had demonstrated the capability of the reverse diode to electrically isolate a fuel cell stack under fault. The proposed experiments focus on the dynamic behaviour of the stack under degraded working modes and point out the key-role of the fuel cell stack impedance in the triggering of the anti-parallel diode switching.

11/00889 Improved electrochemical properties of Ni/YSZ anodes infiltrated by proton conductor SZY in solid oxide fuel cells with dry methane fuel: dependence on amount of SZY

Jin, Y. *et al. Chemical Engineering Science*, 2010, 65, (1), 597–602.

Improved electrochemical properties of Ni/YSZ anodes for solid oxide fuel cells (SOFCs) were obtained when a proton-conducting material, $SrZr_{0.95}Y_{0.05}O_{3-\alpha}$ (SZY), was infiltrated to the anode. The synthesis of SZY in Ni/YSZ anodes involved first adding an SZY precursor solution by the infiltration method and then calcinating at 1300 °C to induce the chemical decomposition reaction of the SZY precursor. When the amount of infiltrated SZY was increased, the performance of SOFCs with Ni/YSZ–SZY increased, while the degradation of the anode decreased in dry methane fuel. Based on the performance, anode potential, and degradation ratio of the SOFCs, the optimal amount of infiltrated SZY was about 1/14 (SZY/NiO by weight). The improved electrochemical properties might be due to electrochemically produced H_2O and the high oxygen coverage near the triple phase boundary of SZY-infiltrated Ni/YSZ.

11/00890 Modelling and simulation of the steady-state and dynamic behaviour of a PEM fuel cell

Sharifi Asl, S. M. *et al. Energy*, 2010, 35, (4), 1633–1646.

The performance of a fuel cell can be expressed by the voltage–load current (V–I) characteristics. In this study, two mathematical modelling for computing the steady-state and dynamic voltage–current (V–I) characteristics of PEM fuel cell stacks have been developed. For determining the humidity of the membrane in steady-state conditions, mathematical and theoretical equations are considered. This value is not an adjustable parameter. The goal of dynamic modelling is to find the response of the system against the load variations. In this research, in addition to the charge double layer phenomenon, the effects of temperature and gas flows are taken into account, then the fuel cell system is divided into three control volumes and thus a lumped-parameter model for these sub-systems is established using the mass and heat transfer equations. The proposed models are implemented in Matlab/Simulink environment. Additionally, these models were tested for the SR-12Modular PEM Generator, the Ballard Mark V FC, the BCS 500-W stack and various experimental data in open literature. They exhibit excellent agreement with other simulation and experimental results.

11/00891 Novel biometric flow slab design for improvement of PEMFC performance

Wang, C.-T. *et al. Applied Energy*, 2010, 87, (4), 1366–1375.

Designing a better flow slab is important to cell performance because of its significant influence on the total pressure drop and flow uniformity. Two novel biometric flow slabs, BFF1 and BFF2, which are addressed in this study, are believed to enhance the capability of oxygen transportation and promote the liquid water removal. Hence, its possession of a higher flow uniformity and lower pressure drop would produce a better power performance than the serpentine and parallel flow. These findings with respect to the design of biometric flow slab could be useful to promote the cell performance of proton exchange membrane (PEM) fuel cells, and could even be expanded to other cell types.

11/00892 Numerical study on channel size effect for proton exchange membrane fuel cell with serpentine flow field

Wang, X.-D. *et al. Energy Conversion and Management*, 2010, 51, (5), 959–968.

This work numerically investigates the effect of the channel size on the cell performance of proton exchange membrane (PEM) fuel cells with serpentine flow fields using a three-dimensional, two-phase model. The local current densities in the PEM, oxygen mass flow rates and liquid water concentrations at the interface of the cathode gas diffusion layer and catalyst layer were analysed to understand the channel size effect. The predictions show that smaller channel sizes enhance liquid water removal and increase oxygen transport to the porous layers, which improve cell performance. Additionally, smaller channel sizes also provide more uniform current density distributions in the cell. However, as the channel size decreases, the total pressure drops across the cell increases, which leads to more pump work. With taking into account the pressure losses, the optimal cell performance occurs for a cell with a flow channel cross-sectional area of $0.535 \times 0.535\,mm^2$.

11/00893 Optimal design of baffles locations with interdigitated flow channels of a centimeter-scale proton exchange membrane fuel cell

Jang, J.-Y. *et al. International Journal of Heat and Mass Transfer*, 2010, 53, (4), 732–743.

In the present study, the simplified conjugate-gradient method (SCGM) was combined with commercial computational fluid dynamics CFD code to build an optimizer for designing the baffles locations with interdigitated channels of a centimetre-scale proton exchange mem-

brane fuel cell (PEMFC). Using the optimizer, the locations of the baffles are adjusted toward the maximization of the average current density of the flow field. The approach is developed by using the commercial CFD code as the direct problem solver, which is able to provide the numerical solutions for the three-dimensional mass, momentum and species transport equations as well as to predict the electron conduction and proton migration taking place in a PEMFC. Results show that the optimal design process of the locations of the baffles can be completed by using the present optimization approach in just a finite number of iterations. The optimization process may lead to an appreciable increase by 14% in the power output from the fuel cell.

11/00894 Preparation of highly loaded Pt/carbon xerogel catalysts for proton exchange membrane fuel cells by the strong electrostatic adsorption method
Job, N. *et al. Catalysis Today*, 2010, 150, (1–2), 119–127.
Pt/carbon xerogel catalysts were prepared by the strong electrostatic adsorption method: impregnation of the support was performed under optimal conditions, leading to maximum metal weight percentage while keeping the highest possible dispersion. After impregnation with H_2PtCl_6, the samples were filtered, dried and reduced. In order to increase the Pt weight percentage, up to three successive impregnation–drying–reduction cycles were performed. The final metal content of the catalysts was found to increase regularly: 7.5, 15.0 and 22.3 wt%, after one, two and three cycles, respectively. This indicates that the adsorption sites were fully regenerated after the reduction treatment, and that they were available for the next impregnation step. In each case, the metal particles were found to be highly dispersed (particle size 2 nm); in addition, the average particle size did not change after repeated impregnation. The 15.0 wt% sample was tested as a cathodic catalyst in an H_2/air proton exchange membrane fuel cell: the cathode activity, expressed as a function of the mass of Pt involved, increased up to twice that of previous catalysts prepared by impregnation with H_2PtCl_6 and reduction in aqueous phase by $NaBH_4$, provided the final reduction temperature of the catalyst was increased up to 450 °C.

11/00895 Production of electricity from the treatment of continuous brewery wastewater using a microbial fuel cell
Wen, Q. *et al. Fuel*, 2010, 89, (7), 1381–1385.
A single air–cathode microbial fuel cell (MFC) was constructed, carbon fibre was used as anode and continuous brewery wastewater as substrate. The MFC displayed a maximum power of 24.1 W m^{-3} (669 mW m^{-2}) and an internal resistance of 23.3 Ω running on raw wastewater (chemical oxygen demand (COD) = 1501 mg L^{-1}). The effect of phosphate buffer solution (PBS) addition and substrate concentration of wastewater on the performance of MFC was demonstrated. Data showed that both PBS addition and increase of substrate concentration had a favourable effect on the electrochemical performance and substrate removal efficiency of the MFC. However, it can be concluded from the polarization curve that MFC operated under raw brewery wastewater had a relatively low internal resistance, which resulted in a favourable performance of the MFC compared with other MFCs using raw wastewater. Thus it is feasible and sustainable in nature because of the utilization of raw wastewater as substrate for *in situ* power generation apart from treatment.

11/00896 Study of a multiphase interleaved step-up converter for fuel cell high power applications
Thounthong, P. and Davat, B. *Energy Conversion and Management*, 2010, 51, (4), 826–832.
This paper presents a study of a high power dc distributed system supplied by a fuel cell generator. A proposed parallel power converter with interleaving algorithm is chosen to boost a low dc voltage of fuel cell to a dc bus utility level. The present interleaved step-up converters are composed of two and four identical boost converters connected in parallel. Converters are controlled by interleaved switching signals, which have the same switching frequency and the same phase shift. By virtue of paralleling the converters, the input current can be shared among the cells or phases, so that high reliability and efficiency in power electronic systems can be obtained. In addition, it is possible to improve the system characteristics such as maintenance, repair, fault tolerance, and low heat dissipation. During the past decade, power electronics research has focused on the development of interleaved parallel converters. For an interleaving technique with a real fuel cell source, this work is the first presentation; it is not just a fuel cell simulation. So, the design and experimental verification of 1.2-kW prototype converters at a switching frequency of 25 kHz connected with a Nexa^{TM} PEM fuel cell system (1.2-kW, 46-A) in a laboratory is presented. Experimental results corroborate the excellent system performances. The fuel cell ripple current can be virtually reduced to zero. As a result, the fuel cell mean current is nearly equal to the fuel cell rms current.

11/00897 Testing of a cathode fabricated by painting with a brush pen for anode-supported tubular solid oxide fuel cells
Liu, R. *et al. Journal of Power Sources*, 2010, 195, (2), 541–545.
The authors have studied the properties of a cathode fabricated by painting with a brush pen for use with anode-supported tubular solid oxide fuel cells (SOFCs). The porous cathode connects well with the electrolyte. A preliminary examination of a single tubular cell, consisting of a Ni–YSZ anode support tube, a Ni–ScSZ anode functional layer, a ScSZ electrolyte film, and a LSM–ScSZ cathode fabricated by painting with a brush pen, has been carried out, and an improved performance is obtained. The ohmic resistance of the cathode side clearly decreases, falling to a value only 37% of that of the comparable cathode made by dip-coating at 850 °C. The single cell with the painted cathode generates a maximum power density of 405 mW cm^{-2} at 850 °C, when operating with humidified hydrogen.

15 ENVIRONMENT

Pollution, health protection, applications

11/00898 A fuzzy multicriteria approach for evaluating environmental performance of suppliers
Awasthi, A. *et al. International Journal of Production Economics*, 2010, 126, (2), 370–378.
This study presents a fuzzy multicriteria approach for evaluating environmental performance of suppliers. The proposed approach consists of three steps. The first step involves identification of criteria for assessing environmental performance of suppliers. In step 2, the experts rate the selected criteria and the various alternatives (suppliers) against each of the criteria. Linguistic assessments are used to rate the criteria and the alternatives. These linguistic ratings are then combined through fuzzy TOPSIS to generate an overall performance score for each alternative. The alternative with the highest score is chosen as the one with highest environmental performance. The advantage of using fuzzy TOPSIS is that it distinguishes between Benefit (the more the better) and the Cost (the less the better) category criteria and selects solutions that are close to the positive ideal solutions and far from negative ideal solutions. In step 3, sensitivity analysis is conducted to evaluate the influence of criteria weights on the environmental performance evaluation of suppliers. The strength of the proposed approach is its practical applicability and ability to provide solution under partial or lack of quantitative information. A numerical application is provided to demonstrate the proposed approach.

11/00899 A general methodology for calculating the MSW management self-sufficiency indicator: application to the wider Barcelona area
Fragkou, M. C. *et al. Resources, Conservation and Recycling*, 2010, 54, (6), 390–399.
In this paper, a new methodology adequate for the separate accounting and analysis of municipal solid waste (MSW) flows of a system is developed, employing the monitoring of these through a metabolic perspective and based on the established MFA methodological guidelines, as proposed by Eurostat in 2001. Additionally, a new indicator is proposed, suitable for the revision of MSW management plans, when combined with the metabolic picture of a system, in line with basic waste management principles. The value of the MSW management self-sufficiency indicator reflects the capacity of a system to manage the amount of MSW it accepts and the grade of sustainability of the treatment practices followed within the system, valuing as the best option the use of residues as raw materials. Compared with waste recovery rates, the new indicator proves to be more comprehensive in assessing the effectiveness of MSW management plans in medium-scale urban regions, evaluating the capacity of a socioeconomic system to close its material circles. In combination with information provided by other urban sustainability indicators, as water use and air pollution, the indicator can be a useful tool in decision-making. In this paper, the case of a highly urbanized coastal Mediterranean area (the city of Barcelona and its surroundings) is studied and assessed for a time period of 8 years.

11/00900 A salt tolerant *Enterobacter cloacae* mutant for bioaugmentation of petroleum- and salt-contaminated soil
Hua, X. *et al. Biochemical Engineering Journal*, 2010, 49, (2), 201–206.

A NaCl-tolerant *Enterobacter cloacae* variant (MU-1) was obtained by mutagenesis using atmospheric pressure glow discharge (APGD) plasmas. The variant exhibited regular growth behaviour in slurry cultivation and reached a cell density of 5.72×10^8 and 6.44×10^8 colony-forming units (CFU/mL) in the presence and absence of 7.5% NaCl, respectively, when crude oil was used as the sole carbon source (crude oil/soil = 1.5%). The total petroleum hydrocarbon (TPH) degradation percentage was 7.94% with mutant MU-1 in the presence of 7.5% NaCl whereas that of the wild-type strain was 3.17%. When cultivated in saline medium, MU-1 showed a slight change in membrane permeability but significant increases in both the K^+ concentration inside the cell membrane (from 234.24 to 1422.88 ppm/g dry cell weight in the first 2 h) and the exopolysaccharide (EPS) level outside the membrane (from 1350 to 1825 mg/g dry cell weight). The rapid increase in K^+ inside the cell and the simultaneous accumulation of EPS outside the cell may be responsible for maintaining the osmotic balance during saline cultivation, and this could facilitate the microbial growth and TPH degradation of MU-1.

11/00901 Biomass energy: employment generation and its contribution to poverty alleviation

Openshaw, K. *Biomass and Bioenergy*, 2010, 34, (3), 365–378.

Studies were undertaken in Malawi from 1995 to 1997 and 2007 to 2008 to estimate the supply and demand of household energy. Because little is known about the supply chain for biomass, surveys were carried out for urban areas on its production, transport and trade as well as sustainable supply. Also, because biomass is used by all people for a multitude of purposes, a complete picture was made of regional and urban biomass supply and demand. The results indicated that biomass is not only the principal energy, accounting for 89% of demand, but also the main traded energy in the two time periods accounting for 56–59% of commercial demand. Petroleum products supplied 26–27%, electricity 8–12% and coal 6–10%. The market value of traded woodfuel was US$48.8 million and US$81.0 million in 1996 and 2008 respectively, about 3.5% of gross domestic product (GDP). The study found that in 1996 and 2008 respectively, the equivalent of 93,500 and 133,000 full-time people was employed in the biomass supply chain, approximately 2% of the potential workforce. In contrast, about 3400 and 4600 people were employed in the supply chain of other fuels in these years. If the Malawi findings are applied to the current estimated wood energy consumption in sub-Saharan Africa, then approximately 13 million people could be employed in commercial biomass energy; this highlights its importance as a means to assist with sustainable development and poverty alleviation.

11/00902 Cultural energy analyses of dairy cattle receiving different concentrate levels

Koknaroglu, H. *Energy Conversion and Management*, 2010, 51, (5), 955–958.

Purpose of this study was to conduct cultural energy analyses of dairy cows receiving different levels of concentrate. Data were acquired by conducting a survey on 132 dairy farms selected by the stratified random sampling method. Dairy cattle farms were divided into three groups according to concentrate level and were analysed. Accordingly concentrate levels were assigned as low (LLC) (<40%, 52 farms), intermediate (ILC) (40–50%, 36 farms) and high (HLC) (>50%, 44 farms). Cultural energy used for feed for cows was calculated by multiplying each ingredient with corresponding values of ingredients from literature. Transportation energy was also included in the analysis. Total cultural energy expended was highest for LLC ($P < 0.05$). Cultural energy expended for feed constituted more than half of the total cultural energy and was highest for LLC ($P < 0.05$). Cultural energy expended per kg milk and per Mcal protein energy was higher for LLC ($P < 0.05$). Efficiency defined as Mcal input/Mcal output was better for ILC and was worse for LLC ($P < 0.05$) and HLC was intermediate thus not differing from other groups. Results show that cultural energy use efficiency does not linearly increases as concentrate level increases and increasing concentrate level does not necessarily mean better efficiency. Thus optimum concentrate level not interfering cows performance should be sought for sustainable dairy production.

11/00903 Direct quadrature method of moments for the exhaust particle formation and evolution in the wake of the studied ground vehicle

Chan, T. L. *et al. Journal of Aerosol Science*, 2010, 41, (6), 553–568.

In the present study, the particle formation and evolution processes, and concentration field in the wake region of the studied ground vehicle for stationary (i.e. low idling mode) and moving (i.e. 10 and 30 km/h modes) conditions in a typical high densely urban road microenvironment were investigated numerically using large eddy simulation (LES) with the aerosol dynamics and dispersion model based on the direct quadrature method of moments (DQMOM) approach. The turbulent dilution and dispersion characteristics, and the complex formation and growth dynamics of exhaust particles behind the studied ground vehicle to the atmosphere were taken into consideration. The results show that the processes of nucleation and coagulation are completed in a short distance away from the vehicular exhaust tailpipe exit of the studied ground vehicle. Due to the nucleation, coagulation and strong dilution by the turbulent exhaust plume that take place behind the studied ground vehicle, the characteristics and behaviour of the average diameter, and the number and volume concentration of the particles are quite different with respect to the studied driving conditions.

11/00904 Effect of tectonics and earthquakes on geothermal activity near plate boundaries: a case study from South Iceland

Khodayar, M. *et al. Geothermics*, 2010, 39, (3), 207–219.

The authors studied fracture-controlled geothermal fields in the Hreppar Rift-Jump Block (HRJB), a micro-plate bounded by two NNE rifts and the E–W transform zone of the South Iceland Seismic Zone (SISZ). Distinguishing whether the extensional rift swarm or the transform zone shear fractures host the geothermal activity is challenging. GPS mapping of 208 springs and tectonic analysis indicate that six Riedel shear fracture sets of an older transform zone in the HRJB are permeable. Northerly dextral strike-slip faults are the principal permeable faults, although the highest discharge and temperature are found at their intersections with other fracture sets. Two northerly faults from the HRJB connect to the source faults of the major 1784 and 1896 earthquakes within the active SISZ. The 1784 earthquake caused pressure changes as far north as the studied springs, indicating that earthquakes keep faults permeable over hundreds of years.

11/00905 Environmental justice, impact assessment and the politics of knowledge: the implications of assessing the social distribution of environmental outcomes

Walker, G. *Environmental Impact Assessment Review*, 2010, 30, (5), 312–318.

Claims of environmental injustice have increasingly become part of environmental conflicts, both explicitly through the work of environmental campaigning groups and implicitly through the arguments deployed about the rights and wrongs of a given situation. Such claims can centre on different notions of justice, including those concerned with questions of distribution and procedure. This paper focuses on distributional or outcome justice and explores what implications follow when the distributional concerns of environmental justice are included in the practice of impact assessment processes, including through social impact assessment (SIA). The current use of impact assessment methods in the UK is reviewed showing that although practices are evolving there is a little routine assessment of distributional inequalities. It is argued that while this should become part of established practice to ensure that inequalities are revealed and matters of justice are given a higher profile, the implications for conflict within decision making processes are not straightforward. On the one hand, there could be scope for conflict to be ameliorated by analysis of inequalities informing the debate between stakeholders, and facilitating the implementation of mitigation and compensation measures for disadvantaged groups. On the other hand, contestation over how evidence is produced and therefore what it shows, and disagreement as to the basis on which justice and injustice are to be determined, means that conflict may also be generated and sustained within what are essentially political and strategic settings.

11/00906 Environmentally damaging electricity trade

de Villemeur, E. B. and Pineau, P. O. *Energy Policy*, 2010, 38, (3), 1548–1558.

Electricity trade across regions is often considered welfare enhancing. This paper shows that this should be reconsidered if environmental externalities are taken into account. Two cases are considered where trade is beneficial, before accounting for environmental damages: first, when two regions with the same technology display some demand heterogeneity; second when one region endowed with hydropower arbitrages with its 'thermal' neighbour. The results show that under reasonable demand and supply elasticities, trade comes with an additional environmental cost. This calls for integrating environmental externalities into market reforms when redesigning the electricity sector. Two North American applications illustrate the results: trade between Pennsylvania and New York, and trade between hydro-rich Quebec and New York.

11/00907 Identifying performance gaps in hydrogen safety sensor technology for automotive and stationary applications

Boon-Brett, L. *et al. International Journal of Hydrogen Energy*, 2010, 35, (1), 373–384.

A market survey has been performed of commercially available hydrogen safety sensors, resulting in a total sample size of 53 sensors from 21 manufacturers. The technical specifications, as provided by the

manufacturer, have been collated and are displayed herein as a function of sensor working principle. These specifications comprise measuring range, response and recovery times, ambient temperature, pressure and relative humidity, power consumption and lifetime. These are then compared against known performance targets for both automotive and stationary applications in order to establish in how far current technology satisfies current requirements of sensor end users. Gaps in the performance of hydrogen sensing technologies are thus identified and areas recommended for future research and development.

11/00908 Impact of inter-sectoral trade on national and global CO_2 emissions: an empirical analysis of China and US

Gao, J. *et al. Energy Policy*, 2010, 38, (3), 1389–1397.

This paper attempts to discuss the CO_2 emissions embodied in Sino-US international trade using a sector approach. Based on an input–output model established in this study, the impact of Sino-US international trade on national and global CO_2 emissions was quantified. The initial findings reveal that: in 2005, the USA reduced 190.13 Mt CO_2 emissions through the consumption of imported goods from China, while increasing global CO_2 emissions by about 515.25 Mt. Similarly, China reduced 178.62 Mt CO_2 emissions through the consumption of US goods, while reducing global CO_2 emissions by 129.93 Mt. Sino-US international trade increased global CO_2 emissions by 385.32 Mt as a whole, of which the chemical, fabricated metal products, non-metallic mineral products and transportation equipment sectors contributed an 86.71% share. Therefore, it is suggested that accelerating the adjustment of China's trade structure and export of US advanced technologies and experience related to clean production and energy efficiency to China is the way to reduce the negative impact of Sino-US trade on national and global CO_2 emissions. This behaviour should take into account the processing and manufacturing industries as a priority, especially the chemical, fabricated metal products, non-metallic mineral products and transportation equipment sectors.

11/00909 Inherent occupational health assessment during preliminary design stage

Hassim, M. H. and Hurme, M. *Journal of Prevention in the Process Industries*, 2010, 23, (3), 476–482.

Chemical process routes can already be assessed as early as in the development and design phases. Process screening should not look at economic and technical aspects only, but also the safety, health, and environmental performances. In this paper, a method called the Health Quotient Index (HQI) is presented for the preliminary process design phase. The HQI provides a simple approach to quantify workers' health risk from exposure to fugitive emissions, e.g. in petrochemical plants. The method utilizes process data from flow sheet diagram, which is already available at the preliminary design stage. Since the mechanical details of the process are still unknown, a database of the precalculated fugitive emissions for typical operations in chemical plants was created to simplify the assessment. The HQI can be used to rank alternative process concepts or to quantify the risk level of processes. As a case study, six process routes for producing methyl methacrylate are discussed. Three health indexes are compared in the case study. The HQI is able to highlight the difference of hazard levels between the routes better as a result of more detailed assessment of the exposures.

11/00910 Primary energy and greenhouse gas implications of increasing biomass production through forest fertilization

Sathre, R. *et al. Biomass and Bioenergy*, 2010, 34, (4), 572–581.

This study analyses the primary energy and greenhouse gas (GHG) implications of increasing biomass production by fertilizing 10% of Swedish forest land. The results show an increased annual biomass harvest of 7.4 million t dry matter, of which 41% is large-diameter stemwood. About 6.9 PJ/year of additional primary energy input is needed for fertilizer production and forest management. Using the additional biomass for fuel and material substitution can reduce fossil primary energy use by 150 or 164 PJ/year if the reference fossil fuel is fossil gas or coal, respectively. About 22% of the reduced fossil energy use is due to material substitution and the remainder is due to fuel substitution. The net annual primary energy benefit corresponds to about 7% of Sweden's total primary energy use. The resulting annual net GHG emission reduction is 11.9 million or 18.1 million tCO_{2equiv} if the reference fossil fuel is fossil gas or coal, respectively, corresponding to 18% or 28% of the total Swedish GHG emissions in 2007. A significant one-time carbon stock increase also occurs in wood products and forest tree biomass. These results suggest that forest fertilization is an attractive option for increasing energy security and reducing net GHG emission.

11/00911 Procedure for probabilistic safety assessment of leaks and breaks of piping systems

Berg, H.-P. *et al. International Journal of Pressure Vessels and Piping*, 2010, 87, (2–3), 94–99.

The estimation of leak and break frequencies in piping systems is part of the probabilistic safety assessment of technical plants. In this paper, a statistical method based on the evaluation of German operational experience for piping systems with different diameters is described because an earlier estimation has been updated and extended introducing new methodical aspects and data. A major point is the inclusion of structural reliability models based on fracture mechanics calculation procedures. As an example of application the statistical estimation method for leak and break frequencies of piping systems with a nominal diameter of 50 mm (the volume control system of a German pressurized water reactor) was updated. Moreover, the evaluation of the operational experience was extended to 341 years with respect to cracks, leaks and breaks in the volume control system of German pressurized water reactors. Using the actual database, new calculations of leak and break frequencies have been performed and the results have been compared with previous values.

11/00912 Quality control and estimation of global solar radiation in China

Tang, W. *et al. Solar Energy*, 2010, 84, (3), 466–475.

Measurements of surface radiation in China are too sparse to meet demand for scientific research and engineering applications. Moreover, the radiation data often include erroneous and questionable values though preliminary quality-check has been done before the data release. Therefore, quality control of radiation data is often a prerequisite for using these data. In this study, a set of quality-check procedures were implemented to control the quality of the solar radiation measurements at 97 stations in China. A hybrid model for estimating global solar radiation was then evaluated against the controlled data. The results show that the model can estimate the global radiation with accuracy of MBE less than 1.5 MJ m^{-2} and RMSE less than 2.8 MJ m^{-2} for daily radiation and RMSE less than 2.0 MJ m^{-2} for monthly-mean daily radiation at individual stations over most of China except at a few stations where unsatisfactory estimates were possibly caused by severe air pollution or too dense clouds. The MBE averaged over all stations are about 0.7 MJ m^{-2} and RMSE about 2.0 MJ m^{-2} for daily radiation and RMSE about 1.3 MJ m^{-2} for monthly-mean daily radiation. Finally, this model was used to fill data gaps and to expand solar radiation data set using routine meteorological station data in China. This data set would substantially contribute to some radiation-related scientific studies and engineering applications in China.

11/00913 SEA monitoring in Swedish regional transport infrastructure plans – improvement opportunities identified in practical experience

Lundberg, K. *et al. Environmental Impact Assessment Review*, 2010, 30, (6), 400–406.

Strategic environmental assessment (SEA) requires monitoring in order to identify unforeseen adverse effects and to enable appropriate remedial action to be taken. Guidelines on how to monitor significant environmental impacts have been developed but experience from practice is limited. This paper presents a study of environmental monitoring in Swedish regional transport infrastructure planning. The result shows that essentially no environmental monitoring is currently performed. Monitoring of the plans merely involves checking the implementation of projects and performing an economic account. At present, a new planning period has commenced for the regional transport infrastructure plans. To obtain an iterative SEA process for the new plan with integrated SEA monitoring, the following means are suggested: reinforcement of practitioners' incentives to plan and perform monitoring; integration of monitoring in the SEA process; pre-determined impact thresholds that prompt remedial action; and more efficient use of monitoring results.

11/00914 The roles of catalysis and reaction engineering in overcoming the energy and the environment crisis

Vlachos, D. G. and Caratzoulas, S. *Chemical Engineering Science*, 2010, 65, (1), 18–29.

An overview of the environmental and energy problems is given with emphasis on the challenges and opportunities for the catalysis and reaction engineering community. Important research directions, entailing the hydrogen economy, process intensification, enhanced efficiency, transformation of underutilized energy resources (e.g. natural gas from remote and offshore locations), and biomass conversion with novel processing schemes, are outlined. Recommendations for future research needs are made.

11/00915 To consume or not: how oil prices affect the comovement of consumption and aggregate wealth

Odusami, B. O. *Energy Economics*, 2010, 32, (4), 857–867.

This paper provides insight into how oil price movements affect the consumption choices of US households through the wealth channel. An earlier study showed that while consumption, asset wealth, and labor income share a common long-term trend; they substantially deviate

from one another in the short run. This study shows that these transitory deviations can be explained by fluctuations in the price of crude oil. Linear and threshold multivariate autoregressive models are used to measure the oil price effect. Oil price effect on the consumption to aggregate wealth ratio is robust to monetary policy effect, sub-period effect, and econometric specifications of oil price effect. Generally speaking, higher (lower) oil price will lead to a decrease (increase) in the proportion of aggregate wealth consumed. In addition, the magnitude of the oil price effect is asymmetric and sub-period dependent. Oil price effect was higher before the 1980s than in succeeding periods.

CO_2, NO_x, SO_2 and particulate emissions

11/00916 A study on the activity of CaO-based sorbents for capturing CO_2 in clean energy processes

Wang, J. *et al. Applied Energy*, 2010, 87, (4), 1453–1458.

CaO-based regenerative sorbents for CO_2 capture in power generation and H_2 production are receiving growing attention. A major challenge for this technology is the decay of sorbent activity with increasing number of the sorption/regeneration cycles. Evaluation of long-term sorbent activity currently requires substantial experimental work. In this study, the dependence of the activity on the number of sorption/regeneration cycles is examined, and the apparent dependence on the number of cycles is related to the duration of sorbent regeneration. By relating the decay in activity of the sorbent to its decrease in surface area due to sintering, interesting insights can be drawn. A method for determination of the long-term activity has been proposed, which can greatly reduce the experimental work for sorbent development and process evaluation.

11/00917 An evaluation of greenhouse gas mitigation options for coal-fired power plants in the US Great Lakes States

Froese, R. E. *et al. Biomass and Bioenergy*, 2010, 34, (3), 251–262.

This study assessed the options for mitigating greenhouse gas emissions from electricity generation in the US Great Lakes States, a region heavily dependent on coal-fired power plants. A proposed 600 MW power plant in northern Lower Michigan, USA provided context for the evaluation. Options to offset fossil CO_2 emissions by 20% included biomass fuel substitution from (1) forest residuals, (2) short-rotation woody crops, or (3) switchgrass; (4) biologic sequestration in forest plantations; and (5) geologic sequestration using CO_2 capture. Review of timber product output data, land cover data, and expected energy crop productivity on idle agriculture land within 120 km of the plant revealed that biomass from forestry residuals has the potential to offset 6% and from energy crops 27% of the annual fossil fuel requirement. Furthermore, annual forest harvest in the region is only 26% of growth and the surplus represents a large opportunity for forest products and bioenergy applications. Life cycle assessment (LCA) was used to compare mitigation options, using fossil energy demand and greenhouse gas emissions per unit electricity generation as criteria. LCA results revealed that co-firing with forestry residuals is the most attractive option and geologic sequestration is the least attractive option, based on the two criteria. Biologic sequestration is intermediate but likely infeasible because of very large land area requirements. The study revealed that biomass feedstock potentials from land and forest resources are not limiting mitigation activities, but the most practical approach is likely a combination of options that optimize additional social, environmental and economic criteria.

11/00918 Analyses of CO_2 emissions embodied in Japan–China trade

Liu, X. *et al. Energy Policy*, 2010, 38, (3), 1510–1518.

This paper examines CO_2 emissions embodied in Japan–China trade. Besides directly quantifying the flow of CO_2 emissions between the two countries by using a traditional input–output (IO) model, this study also estimates the effect of bilateral trade to CO_2 emissions by scenario analysis. The time series of quantifications indicate that CO_2 emissions embodied in exported goods from Japan to China increased overall from 1990 to 2000. The exported CO_2 emissions from China to Japan greatly increased in the first half of the 1990s. However, by 2000, the amount of emissions had reduced from 1995 levels. Regardless, there was a net export of CO_2 emissions from China to Japan during 1990–2000. The scenario comparison shows that the bilateral trade has helped the reduction of CO_2 emissions. On average, the Chinese economy was confirmed to be much more carbon-intensive than Japan. The regression analysis shows a significant but not perfect correlation between the carbon intensities at the sector level of the two countries. In terms of CO_2 emission reduction opportunities, most sectors of Chinese industry could benefit from learning Japanese technologies that produce lower carbon intensities.

11/00919 Biotransformations of carbon dioxide in photobioreactors

Jacob-Lopes, E. *et al. Energy Conversion and Management*, 2010, 51, (5), 894–900.

Laboratory experiments were performed to study the capacity of CO_2 sequestration and carbon fixation into biomass during the cultivation of the cyanobacteria *Aphanothece microscopica Nägeli* in refinery wastewater. The influence of the photoperiod (day/night) on the rates of CO_2 sequestration and O_2 release was also determined. Rates of CO_2 sequestration were measured both in the liquid and gaseous phases. The results showed that the capacity of CO_2 sequestration and O_2 release during the day/night experiment was about one-fourth less than that achieved in the continuously illuminated experiment. Equivalence was found between rates of CO_2 sequestration measured in the two phases. Despite large amounts of CO_2 that were sequestered during the cultivation, it is demonstrated that only a small fraction (about 3%) was effectively fixed as microalgae biomass, indicating the existence of other routes of CO_2 conversion in the photobioreactor.

11/00920 CO_2 removal using membrane gas absorption

Ahmad, A. L. *et al. International Journal of Greenhouse Gas Control*, 2010, 4, (3), 495–498.

The objective of this study was to investigate the potential process for the removal of CO_2 from flue gas using a fundamental membrane contactor, which is a membrane gas absorption (MGA) system. The experiments consisted of microporous polyvinylidenefluoride (PVDF) flat sheet membrane with 0.1 μm (as module I) and 0.45 μm (as module II) pore size. 2-Amino-2-methyl-1-propanol (AMP) solution was employed as the liquid absorbent. The effect of AMP concentration was studied with variation in the range 1–5 M. In addition, the experiments were carried out with 10%, 20%, 30% and 40% gas ratio of CO_2 to N_2 and pure CO_2 as well. Through contact angle measurement, membranes for module I and module II were obtained with CA values of around 130.25° and 127.77°, respectively. The mass transfer coefficients for module II are lower than those of module I for 1–5 M of AMP. Furthermore, the increase in CO_2 concentration in the feed gas stream enhanced the CO_2 flux as the driving force of the system was increased in sequence from 1 M to 5 M of AMP. However, after the particular percentage (40%) of CO_2 inlet concentration, the CO_2 fluxes seem saturated. The combination of AMP as liquid absorbent and PVDF microporous membrane in MGA system has shown the potential to remove the CO_2 from flue gas. In addition, the higher AMP concentration gave higher mass transfer coefficient at low liquid flow rates.

11/00921 Cryogenic CO_2 capture using dynamically operated packed beds

Tuinier, M. J. *et al. Chemical Engineering Science*, 2010, 65, (1), 114–119.

In this work, a novel post-combustion CO_2 capture process concept is proposed and developed, based on cryogenic CO_2 freeze-out in dynamically operated packed beds. When feeding a flue gas containing CO_2, H_2O and inert gases to a previously refrigerated packed bed, an effective separation between CO_2, H_2O and the permanent gases can be achieved on the basis of differences in dew and sublimation points. Temperature and concentration fronts will develop, which move through the bed with different velocities. H_2O and CO_2 will condensate and desublimate, respectively, extracting the cold energy stored in the packing and therefore avoiding unacceptable pressure drop or plugging. The great advantage is that both H_2O and CO_2 can be separated from a flue gas simultaneously, circumventing costly pretreatment steps. Furthermore, no chemical absorbent or elevated pressures are required. Experiments have been carried out and demonstrated that CO_2 can be well separated from N_2. The process is described by a pseudo-homogeneous one-dimensional model. The resulting simulations show good resemblance with experiments.

11/00922 Emissions from a diesel car during regeneration of an active diesel particulate filter

Dwyer, H. *et al. Journal of Aerosol Science*, 2010, 41, (6), 541–552.

The California Air Resources Board (CARB) and the Joint Research Center of the European Commission (JRC) have collaborated on emissions testing of a light duty diesel vehicle, which is Euro 4 compliant and comes equipped with a diesel particulate filter (DPF). The California testing included an investigation of the regeneration of the DPF over cruise conditions and NEDC test cycles. DPF regeneration is caused by the buildup of soot in the filter, and for the present test vehicle the regeneration process is assisted by a fuel borne catalyst. Regulated exhaust emissions increased substantially during the regeneration events; however, PM emissions levels were below California LEVII emissions standards. There was a very large

increase of volatile particles between 5 and 10 nm, and these volatile particles were generated during all of the observed regeneration events. It appears that the particle number instruments that use the PMP methodology do not capture the PM mass increase during DPF regeneration; however, for one regeneration event there was an apparent large increase in solid particles below the PMP size limit. The PM mass increase associated with regeneration appears to be due to semi-volatile particles collected on filters. During the testing, the regeneration events exhibited considerable variations in the time for regeneration as well as the amount of PM emissions. From this investigation, several questions have been posed concerning the emission of very small (<20 nm) volatile and solid particles during DPF regeneration that need further investigation.

11/00923 Experimental study on particulate and NO_x emissions of a diesel engine fueled with ultra low sulfur diesel, RME-diesel blends and PME-diesel blends

Zhu, L. *et al. Science of The Total Environment*, 2010, 408, (5), 1050–1058.

Ultra-low sulfur diesel (ULSD) and two different kinds of biodiesel fuels blended with baseline diesel fuel in 5% and 20% v/v were tested in a Cummins 4BTA direct injection diesel engine, with a turbocharger and an intercooler. Experiments were conducted under five engine loads at two steady speeds (1500 and 2500 rpm). The study aimed to investigate the engine performance, NO_x emission, smoke opacity, particulate matter (PM) composition, PM size distribution and comparing the impacts of low sulfur content of biodiesel with ULSD on the particulate emission. The results indicate that, compared to base diesel fuel, the increase of biodiesel in blends could cause certain increase in both brake specific fuel consumption and brake thermal efficiency. Compared with baseline diesel fuel, the biodiesel blends bring about more NO_x emissions. With the proportion of biodiesel increase in blends, the smoke opacity decreases, while total particle number concentration increases. Meanwhile the ULSD gives lower NO_x emissions, smoke opacity and total number concentration than those of baseline diesel fuel. In addition, the percentages of SOF and sulfate in particulates increase with biodiesel in blends, while the dry soot friction decreases obviously. Compared with baseline diesel fuel, the biodiesel blends increase the total nucleation number concentration, while ULSD reduces the total nucleation number concentration effectively, although they all have lower sulfur content. It means that, for ULSD, the lower sulfur content is the dominant factor for suppressing nucleation particles formation, while for biodiesel blends, lower volatile, lower aromatic content and higher oxygen content of biodiesel are key factors for improving the nucleation particles formation. The results demonstrate that the higher NO_x emission and total nucleation number concentration are considered as the big obstacles of the application of biodiesel in diesel engine.

11/00924 Flue gas desulfurization by citrate process and optimization of working parameters

Akyalçin, L. and Kaytakoğlu, S. *Chemical Engineering and Processing: Process Intensification*, 2010, 49, (2), 199–204.

In this study, model flue gas was bubbled into 0.25 L tribasic sodium citrate (TSC) solution being in 0.5 L glass absorber to remove its SO_2 content. Size of gas bubbles, absorption temperature, gas flow rate, solution concentration and stirring rate were taken as working parameters to investigate their effect on SO_2 removal from flue gas. The Taguchi experimental design method was used to obtain optimum values of working parameters for SO_2 saturation time of the TSC solution selected as a quality characteristic. The optimum levels of parameters to maximize the SO_2 saturation time of TSC solution were coarse bubbles for gas delivery, 35 °C for absorption temperature, 1.5 slm for gas flow rate, 0.5 M for TSC solution concentration and 500 rpm for stirring rate. Under these conditions, the SO_2 saturation time of the TSC solution was achieved as 511 min in average. The most effective parameters on the absorption of SO_2 in TSC solutions were ranked to the least as solution concentration, gas flow rate, size of gas bubbles, absorption temperature and stirring rate.

11/00925 Nitrates removal from polluted aquifers using (Sn or Cu)/Pd catalysts in a continuous reactor

Palomares, A. E. *et al. Catalysis Today*, 2010, 149, (3–4), 348–351.

The aim of this work was to study the catalytic removal of nitrates in natural water (not the water prepared in the laboratory by adding a nitrate salt to distilled water) from polluted aquifers, using a continuous stirred tank reactor. The catalysts studied were (Cu or Sn)/Pd supported on alumina. The activity and selectivity of these catalysts in different types of polluted waters was analysed, optimizing the Pd–metal ratio and the reaction conditions. The deactivation of the catalysts, when using different types of water, was studied and discussed.

11/00926 Refrigeration plants using carbon dioxide as refrigerant: measuring and modelling the solubility and diffusion of carbon dioxide in polymers used as sealing materials

von Solms, N. and Kristensen, J. *International Journal of Refrigeration*, 2010, 33, (1), 19–25.

Because of increased environmental pressure, there is currently a movement away from more traditional refrigerants such as HCFC's toward refrigerants with lower global warming potential such as carbon dioxide (CO_2). However, the use of CO_2 as a refrigerant requires a refrigeration cycle with greater extremes of pressure, placing greater demands on the polymer materials used for seals and packing. The authors have measured the solubility and diffusivity of gaseous CO_2 in two polymers used as sealing materials in CO_2 refrigeration plants. These are hydrogenated nitrile butadiene rubber and ethylene propylene diene monomer which are used in seals such as O-rings. The experiments were performed on a high-pressure microbalance. Solubility results were modelled using an equation of state for polymers (simplified PC-SAFT). The necessary polymer parameters were obtained using a previously published method. The measured results can be successfully correlated using simplified PC-SAFT.

11/00927 Separation of CO_2 from flue gas using electrochemical cells

Pennline, H. W. *et al. Fuel*, 2010, 89, (6), 1307–1314.

Past research with high temperature molten carbonate electrochemical cells has shown that carbon dioxide can be separated from flue gas streams produced by pulverized coal combustion for power generation. However, the presence of trace contaminants, i.e. sulfur dioxide and nitric oxides, will impact the electrolyte within the cell. If a lower temperature cell could be devised that would utilize the benefits of commercially-available, upstream desulfurization and denitrification in the power plant, then this CO_2 separation technique can approach more viability in the carbon sequestration area. Recent work has led to the assembly and successful operation of a low temperature electrochemical cell. In the proof-of-concept testing with this cell, an anion exchange membrane was sandwiched between gas-diffusion electrodes consisting of nickel-based anode electrocatalysts on carbon paper. When a potential was applied across the cell and a mixture of oxygen and carbon dioxide was flowed over the wetted electrolyte on the cathode side, a stream of CO_2 to O_2 was produced on the anode side, suggesting that carbonate/bicarbonate ions are the CO_2 carrier in the membrane. Since a mixture of CO_2 and O_2 is produced, the possibility exists to use this stream in oxy-firing of additional fuel. From this research, a novel concept for efficiently producing a carbon dioxide rich effluent from combustion of a fossil fuel was proposed. Carbon dioxide and oxygen are captured from the flue gas of a fossil-fuel combustor by one or more electrochemical cells or cell stacks. The separated stream is then transferred to an oxy-fired combustor which uses the gas stream for ancillary combustion, ultimately resulting in an effluent rich in carbon dioxide. A portion of the resulting flow produced by the oxy-fired combustor may be continuously recycled back into the oxy-fired combustor for temperature control and an optimal carbon dioxide rich effluent.

11/00928 Structured catalysts containing Co, Ba and K supported on modified natural sepiolite for the abatement of diesel exhaust pollutants

Milt, V. G. *et al. Chemical Engineering Journal*, 2010, 157, (2–3), 530–538.

Natural sepiolite-supported catalysts, structured as highly porous ceramic discs were investigated for their application in diesel exhaust after treatment. Catalysts containing cobalt, potassium and barium, which are active ingredients for diesel soot combustion and NO_x adsorption, were prepared by wet impregnation of the support materials. The influence of incorporating CeO_2 as additive to the clay (sepiolite), along with activated carbon as a pore-generating agent which is eliminated during the heat treatment step was studied. The additives affect the textural properties of the discs that are related with their permeability and filtering capacity, but do not significantly alter their catalytic properties when Co and K are present as the active ingredients. The solids were characterized by several techniques: N_2 adsorption, mercury intrusion porosimetry, TGA-DTA, TPR, XRD and SEM. Different weight losses were observed as the temperature increased in TGA-DTA experiments owing to dehydrations and dehydroxylations of the sepiolite structure. The maximum rate of soot combustion for the Co- and K-containing catalyst was 366 and 453 °C for tight and loose contact, respectively. The bare sepiolite practically does not interact with NO + O_2, however, the addition of potassium and/or Ba caused a notable increase in the NO_x adsorption capacity. The catalytic activity results for the Co,K/sepiolite system and the excellent rheological properties of pastes that allow extrusion in various shapes which on heat treatment leads to conformed ceramic bodies with high mechanical strength, thermal resistance and large

surface areas make this material an interesting potential candidate for the development of catalytic filters for diesel exhaust abatement applications.

Hydrocarbon emissions

11/00929 Solubility prediction of polycyclic aromatic hydrocarbons in non-aqueous solvent mixtures

Jouyban, A. *et al. Fluid Phase Equilibria*, 2010, 293, (1), 47–58.

This study aimed to evaluate the applicability of the Jouyban–Acree model for predicting the solubility of polycyclic aromatic hydrocarbons (PAHs) in binary and ternary solvent mixtures at different temperatures by employing a large solubility data set. The solubility is predicted in solvent mixtures at different temperatures within an acceptable error range based on the experimental solubility data of PAHs in monosolvents. The results reveal that the Jouyban–Acree model could be recommended for practical applications in chemical industries.

Life cycle analysis

11/00930 Comparative LCA of methanol-fuelled SOFCs as auxiliary power systems on-board ships

Strazza, C. *et al. Applied Energy*, 2010, 87, (5), 1670–1678.

Fuel cells own the potential for significant environmental improvements both in terms of air quality and climate protection. Through the use of renewable primary energies, local pollutant and greenhouse gas emissions can be significantly minimized over the full life cycle of the electricity generation process, so that marine industry accounts renewable energy as its future energy source. The aim of this paper is to evaluate the use of methanol in solid oxide fuel cells (SOFC), as auxiliary power systems for commercial vessels, through life cycle assessment (LCA). The LCA methodology allows the assessment of the potential environmental impact along the whole life cycle of the process. The unit considered is a 20 kWel fuel cell system. In a first part of the study different fuel options have been compared (methanol, bio-methanol, natural gas, hydrogen from cracking, electrolysis and reforming), then the operation of the cell fed with methanol has been compared with the traditional auxiliary power system, i.e. a diesel engine. The environmental benefits of the use of fuel cells have been assessed considering different impact categories. The results of the analysis show that fuel production phase has a strong influence on the life cycle impacts and highlight that feeding with bio-methanol represents a highly attractive solution from a life cycle point of view. The comparison with the conventional auxiliary power system shows extremely lower impacts for SOFCs.

11/00931 Energy use, CO_2 emissions and waste throughout the life cycle of a sample of hotels in the Balearic Islands

Rosselló-Batle, B. *et al. Energy and Buildings*, 2010, 42, (4), 547–558.

Tourism is the most developed economic sector in the Balearic Islands. The great rise in construction activities within the last 50 years, the increase in energy use, in CO_2 emissions and in waste production due to tourism, as well as an electrical energy production system mainly based on coal and fossil fuels is not an environmentally sustainable scenario. The aim of this study is to identify the processes that have had the greatest impact on the life cycle of a tourist building. In order to do this, the energy uses, CO_2 emissions and waste materials generated have been estimated, assuming a life cycle of 50 years, within a sample of hotels from the Balearic Islands. The results show that the operating phase, which represents between 70% and 80% of the total energy use, is the one with the greatest impact; that the energy use due to the manufacture of materials represents a fifth of the total and that electric consumption is the main cause of CO_2 emissions because of the regional energy system.

11/00932 LCA of domestic and centralized biomass combustion: the case of Lombardy (Italy)

Caserini, S. *et al. Biomass and Bioenergy*, 2010, 34, (4), 474–482.

This paper analyses and compares the environmental impacts of biomass combustion in small appliances such as domestic open fireplaces and stoves, and in two types of centralized combined heat and power plants, feeding district heating networks. The analysis is carried out following a life cycle assessment (LCA) approach. The expected savings of greenhouse gases (GHG) emissions due to the substitution of fossil fuels with biomass are quantified, as well as emissions of toxic pollutants and substances responsible for acidification and ozone formation. The LCA results show net savings of GHG emissions when using biomass instead of conventional fuels, varying from 0.08 to 1.08 t of CO_2 eq. per t of dry biomass in the different scenarios. Avoided GHG emissions thanks to biomass combustion in Lombardy are 1.32 Mt year^{-1} (1.5% of total regional GHG emissions). For the other impact categories, the use of biomass in district heating systems can again cause a consistent reduction of impacts, whereas biomass combustion in residential devices shows higher impacts than fossil fuels with a particular concern for PAH, VOC and particulate matter emissions. For example, in Lombardy, PM10 emissions from domestic devices are about 8100 t year^{-1}, corresponding to almost one-third of the total particulate emissions in 2005.

11/00933 Life cycle assessment of village electrification based on straight jatropha oil in Chhattisgarh, India

Gmünder, S. M. *et al. Biomass and Bioenergy*, 2010, 34, (3), 347–355.

A decentralized power generation plant fuelled by straight jatropha oil was implemented in 2006 in Ranidhera, Chhattisgarh, India. The goal of this study was to assess the environmental sustainability of that electrification project in order to provide a scientific basis for policy decisions on electrifying remote villages. A full life cycle assessment was conducted on jatropha-based rural electrification and then compared with other electrification approaches such as photovoltaic, grid connection and a diesel-fuelled power generator. In summary, the jatropha-based electrification in Ranidhera reduces greenhouse gas emissions over the full life cycle by a factor of seven compared to a diesel generator or grid connection. The environmental performance is only slightly improved, mainly due to the high air pollution from pre-heating the jatropha seeds. With additional measures oil extraction and overall efficiency could be further improved. However, environmental benefits can only be achieved if jatropha is cultivated on marginal land and land use competition can be excluded. Under these conditions, jatropha-based electricity generation might be a useful alternative to other renewable electrification options, as the technology is very sturdy and can be maintained even in remote and highly under-developed regions.

11/00934 Optimization and life-cycle cost of health clinic PV system for a rural area in southern Iraq using HOMER software

Al-Karaghouli, A. and Kazmerski, L. L. *Solar Energy*, 2010, 84, (4), 710–714.

This paper addresses the need for electricity of rural areas in southern Iraq and proposes a photovoltaic (PV) solar system to power a health clinic in that region. The total daily health clinic load is 31.6 kW h and detailed loads are listed. The National Renewable Energy Laboratory (NREL) optimization computer model for distributed power, 'HOMER', is used to estimate the system size and its life-cycle cost. The analysis shows that the optimal system's initial cost, net present cost, and electricity cost is US$50,700, US$60,375, and US$0.238/kW h, respectively. These values for the PV system are compared with those of a generator alone used to supply the load. It was found that the initial cost, net present cost of the generator system, and electricity cost are US$4500, US$352,303, and US$1.332/kW h, respectively. Using the PV system was concluded as justifiable on humanitarian, technical, and economic grounds.

11/00935 Sensitivity of the LCA allocation procedure for BFS recycled into pavement structures

Sayagh, S. *et al. Resources, Conservation and Recycling*, 2010, 54, (6), 348–358.

The purpose of this paper is twofold: to investigate the problems involved when performing an environmental assessment of various pavements structures and to establish the method applied to solutions proposed by official French guidelines. This assessment will be performed by employing the life cycle assessment (LCA) methodology specifically adapted to road pavements through a parametric environmental evaluation tool developed by LCPC: ERM (elementary road modulus). The paper will also detail the assessment methodology using this same ERM method. The issues of resources conservation and waste allocation will be examined for the case of blast furnace slag (BFS) recycling. Special focus will be placed on the sensitivity of environmental indicators as regards to the waste allocation procedure implemented in the ERM. Two distinct mass ratios (0% and 20%) of steel production have been assigned to BFS and tested on indicators results as hypotheses H1 and H2, respectively. Classical indicators have been calculated using a simplified model to allocate output flows into several impact categories. Results show that the structure using BFS contributes to saving binder extracted from natural resources, yet also consumes a larger mass of natural aggregates. All indicators except for toxicity were found to be very sensitive to the choice of H1 or H2 hypotheses.

16 ENERGY

Supplies, policy, economics, forecasts

11/00936 Correlation between standards and the lifetime commissioning
Djuric, N. and Novakovic, V. *Energy and Buildings*, 2010, 42, (4), 510–521.
This paper reviews the applicability and drawbacks of available European and international standards related to lifetime commissioning, by structuring them into Norwegian commissioning procedures. The work describes research on lifetime commissioning that proposes a generic framework on building performances. The generic framework describes a component in HVAC system by performances. The results of the standard review show that there is a need for measurement and testing standards in hydronic systems. In addition, there is no generic framework on the definition of energy-efficiency measure in the reviewed standards. Findings on a case study, where lifetime commissioning procedures were tested, are presented. After the performances of the case study were defined by the generic framework, it was found that 20% of all the performances can be monitored by a building energy management system. Due to good operation, the building managed to achieve 3% lower energy consumption than design a year after the building was taken in use. In addition, results show that energy signature curves can be used only in a modified manner to predict heating consumption, while electricity consumption cannot be described in that way.

11/00937 Demand response resources: who is responsible for implementation in a deregulated market?
Greening, L. A. *Energy*, 2010, 35, (4), 1518–1525.
Demand response resources (DRR) have potential to offer substantial benefits in the form of improved economic efficiency in wholesale electricity markets. Those benefits include better capacity factors for existing capacity, reductions in requirements for new capacity, enhanced reliability, relief of congestion and transmission constraints, reductions in price volatility, mitigation of market power and lower electricity prices for consumers. However, DRR has been slow to penetrate. There has been substantial disagreement as to which entities in a restructured market should promote the expanded implementation of DRR. This paper contends that no single entity can perform this function. But rather, wider implementation will need to accrue from coordinated actions along the electricity supply chain.

11/00938 Effect of sanctions starts to spread across Iranian energy sector
Anon., *Oil and Energy Trends*, 2010, 35, (9), 3–6.
Further sanctions imposed on Iran are making it increasingly difficult not only to obtain refined produces such as gasoline and aeroplane fuel, but also for the country's own energy production industries to function. Iran does not have the refinery capability to produce the products it needs and so relies on imported supplies. The crude oil Iran does produce is becoming more difficult to sell and the plans to expand the Iranian energy sectors by exporting LNG and gas are threatened because of lack of funds and expertise.

11/00939 Energy, industry and politics: energy, vested interests, and long-term economic growth and development
Moe, E. *Energy*, 2010, 35, (4), 1730–1740.
The article seeks to explicate a link between energy and long-term economic growth and development. While in many ways intuitive, attempts at sketching theoretical frameworks explicating this link have been few and simplistic, typically limited to technology and economics. This article emphasizes the importance of politics as well, fostering a symbiosis between the dominant industries of a historical epoch and the energy system that enabled them to flourish. The framework combines Joseph Schumpeter and Mancur Olson, emphasizing (1) the importance of structural economic change for long-term growth and development and (2) vested interests. The framework yields one theoretical proposition: In order to rise, states must prevent vested interests from blocking structural change. States that are unable to do this will get locked into yesterday's technologies, industries and energy systems, effectively consigning themselves to stagnation and decline. A brief empirical section provides historical data from six historical epochs (including present-day renewables) over a period of 250 years to demonstrate the usefulness of the approach. While no exhaustive test, the data suggests that countries that have prevented vested interests from blocking change have been far more successful in fostering a symbiosis between energy and industry than those countries that have not.

11/00940 Evidence of causality between the quantity and quality of energy consumption and economic growth
Warr, B. S. and Ayres, R. U. *Energy*, 2010, 35, (4), 1688–1693.
This paper re-examines the energy–GDP relationship for the USA for the period 1946–2000 by redefining energy in terms of exergy (the amount of energy available for useful work) and the amount of useful work provided from energy inputs. This led to an examination of whether output growth depends on either the quantity of energy supplied and/or the efficiency of energy use. Two multivariate models were estimated involving GDP, capital, labour and the two measures of energy. It was found that unidirectional causality runs from either energy measure to GDP. The causation was attributed to both short- and long-run effects in the case of exergy, but only long-run effects in the case of useful work. No evidence was found of causality running from GDP to either energy measure. From this it was inferred that output growth does not drive increased energy consumption and to sustain long-term growth it is necessary to either increase energy supplies or increase the efficiency of energy usage. Faced with energy security concerns and the negative externalities of fossil fuel use the latter option is preferred.

11/00941 Global economic activity and crude oil prices: a cointegration analysis
He, Y. *et al. Energy Economics*, 2010, 32, (4), 868–876.
This paper empirically investigates the cointegrating relationship between crude oil prices and global economic activity. The Kilian economic index is used as an indicator of global economic activity. Based on a supply–demand framework and the cointegration theory, the authors find that real futures prices of crude oil are cointegrated with the Kilian economic index and a trade weighted US dollar index, and crude oil prices are influenced significantly by fluctuations in the Kilian economic index through both long-run equilibrium conditions and short-run impacts. An empirically stable, data-coherent and single-equation error-correction model (ECM) which has sensible economic properties is also developed. Empirical results based on the ECM show that the adjustment implied by a permanent change in the Kilian economic index is a relatively drawn-out process.

11/00942 Measurement and evaluation of sustainable development: a composite indicator for the islands of the north Aegean region, Greece
Kondyli, J. *Environmental Impact Assessment Review*, 2010, 30, (6), 347–356.
This paper develops a methodology to analyse, measure and evaluate sustainable development. A holistic approach (systems analysis) is applied to operationalize the sustainable development concept and an integrated approach (composite indicator construction) is adopted for the measurement of sustainable development. The operationalization of the sustainable development concept is based on an in-depth systems analysis of issues associated with economic, social and environmental problems in a policy context. The composite indicator (overall sustainability index) is developed based on the three composite sub-indicators of the sustainable development dimensions. The valuation of the sustainable development is based both on the aggregated sub-indicators and the overall composite indicator. The methodology is used to evaluate the sustainable development of the north Aegean islands between different temporal points. The assessment of the change in the islands' sustainable development is based on a quartile grading scale of the overall sustainable development composite scores.

11/00943 Minding the gap: World Bank's assistance to power shortage mitigation in the developing world
Heffner, G. *et al. Energy*, 2010, 35, (4), 1584–1591.
This paper describes the World Bank's technical assistance and lending efforts in support of developing countries facing power shortages. The paper reviews the World Bank's experience in helping governments to mitigate power shortages in Africa, South Asia, East Asia, and Latin America regions. The paper stresses the need to consider each power 'crunch' on an individual basis, and describes the process used in diagnosing a shortage situation and prescribing mitigation strategies. Several brief case studies are presented, including Botswana, Brazil, Uganda, and South Africa. The political and customer-centric dimensions of power shortage mitigation are briefly described, with suggestions for minimizing the socio-economic impacts of power shortages on the urban and rural poors. The paper concludes that an integrated supply–demand portfolio approach works best, and within the portfolio a mix of market-based rationing, emergency mobilization of customer-owned generation, interruptible rates, load control, and energy efficient lighting should be sought. Although the best formulation will vary according to market structure, demand composition, and nature of the crisis, World Bank practitioners have found one program that works almost everywhere to produce fast and effective results – mass-market compact fluorescent lamp replacement programs.

11/00944 Obtaining biodiesel from Spanish used frying oil: issues in meeting the EN 14214 biodiesel standard
Berrios, M. *et al. Biomass and Bioenergy*, 2010, 34, (3), 312–318.
The biodiesel production from Spanish used frying oils has been studied using two operation flow charts: two-step alkaline transesterification and sequential esterification–transesterification, followed by washing in water in both cases, in order to set out the most suitable operational conditions to achieve the highest FAME percentage in the shortest time. Sequential esterification–transesterification reached slightly better results than two-step alkaline transesterification. The resulting product cannot be called biodiesel as the specifications of EN 14214 Standards have not been met. Specifically, FAME content and kinematic viscosity were outside the requirements because of the chemical modifications which took place in the oil during cooking (presence of polar compounds). The influence of polar compounds on the processes has been studied by means of their analysis in the oil and the product.

11/00945 Optimizing production with energy and GHG emission constraints in Greece: an input–output analysis
Hristu-Varsakelis, D. *et al. Energy Policy*, 2010, 38, (3), 1566–1577.
Under its Kyoto and EU obligations, Greece has committed to a greenhouse gas (GHG) emissions increase of at most 25% compared to 1990 levels, to be achieved during the period 2008–2012. Although this restriction was initially regarded as being realistic, information derived from GHG emissions inventories shows that an increase of approximately 28% has already taken place between 1990 and 2005, highlighting the need for immediate action. This paper explores the reallocation of production in Greece, on a sector-by-sector basis, in order to meet overall demand constraints and GHG emissions targets. A constrained optimization problem is posed, taking into account the Greek environmental input–output matrix for 2005, the amount of utilized energy and pollution reduction options. Two scenarios were examined, limiting fluctuations in sectoral production to at most 10% and 15%, respectively, compared to baseline (2005) values. The results indicate that (i) GHG emissions can be reduced significantly with relatively limited effects on GVP growth rates, and that (ii) greater cutbacks in GHG emissions can be achieved as more flexible production scenarios are allowed.

11/00946 Problems and perspectives in nanostructured carbon-based electrodes for clean and sustainable energy
Centi, G. and Perathoner, S. *Catalysis Today*, 2010, 150, (1–2), 151–162.
Nanostructured carbon-based electrodes for clean and sustainable energy are of increasing relevance. This article highlights critically some selected aspects. These are: (i) the nanoarchitecture of the electrode, (ii) the synthesis methods and the possibility of structuring the inner nanospace of carbon nanotube, i.e. nano-in-nano design, (iii) the problem of nanointerfaces and charge transport, (iv) the interrelation between the dynamics of surface reconstruction of Pt nanoparticles under operation and charge transport limitations, (v) the multiple phenomena governing the performances of advanced electrodes for proton exchange membrane fuel cells, (vi) the use of advanced nanostructured carbon-based electrodes for the electrocatalytic reduction of CO_2 to fuel, and (vii) the modification in the redox properties of transition metals via nanoconfinement within the channels of carbon nanotubes. Finally, the authors consider the need of introducing into catalyst design some of the recent developments made in the field of nanostructured electrodes.

11/00947 Stakeholder attitudes on carbon capture and storage – an international comparison
Johnsson, F. *et al. International Journal of Greenhouse Gas Control*, 2010, 4, (2), 410–418.
This paper presents results from a survey of stakeholder attitudes towards carbon capture and storage (CCS). The survey is the first to make a global comparison across three major regions: North America, Japan, and Europe. It is based on a 30-question survey which targeted individuals working at stakeholder organizations that seek to shape, and will need to respond to, policy on CCS, including electric utilities, oil and gas companies, CO_2-intensive industries and non-governmental organizations (NGOs). The paper reports results from the original survey carried out in 2006 and from a recent follow up on key CCS questions (April 2009). The results show generally small differences across the regions and between the different groups of stakeholders. All believed that the challenge of significant reductions in emissions using only current technologies was severe. There was a widespread belief that CCS as well as renewable technologies such as solar power will achieve major market entry into the electricity sector within the next 10–20 years, whereas there is more scepticism about the role of hydrogen and especially nuclear fusion in the next 50 years. All groups were generally positive towards renewable energy. Yet, there were some notable areas of disagreement in the responses, for example, as expected, NGOs considered the threat of climate change to be more serious than the other groups. North American respondents were more likely to downplay the threat compared to those of the other regions. The Japanese were more concerned about the burden that would be placed on industry in the coming decade as a result of emissions constraints and NGOs were more likely to believe that the burden imposed would be light or very light. NGO respondents also believed CCS to be far more attractive than nuclear power (fission) but much less than renewables. As expected, the risk for leakage from reservoirs was ranked number one of the risk options given. The follow-up study generally confirmed the results of the original study with a few notable differences. As expected, the results of the follow-up shows that respondents consider CCS to play an increased role in the national climate debate. In Japan, there was an increased fraction of respondents who claimed that their organization has a clear position on CCS.

11/00948 Sustainable energy, environmental and agricultural policies in Turkey
Kaygusuz, K. *Energy Conversion and Management*, 2010, 51, (5), 1075–1084.
Turkey's demand for energy and electricity is increasing rapidly. Turkey is heavily dependent on expensive imported energy resources which places a big burden on the economy, also air pollution is becoming a great environmental concern in the country. As would be expected, the rapid expansion of energy production and consumption has brought with it a wide range of environmental issues at the local, regional and global levels. With respect to global environmental issues, Turkey's carbon dioxide emissions have grown along with its energy-consumption. States have played a leading role in protecting the environment by reducing emissions of greenhouse gases. In this regard, renewable energy resources appear to be the one of the most efficient and effective solutions for clean and sustainable energy development in Turkey. Turkey's geographical location has several advantages for extensive use of most of these renewable energy sources and so offers clear potential in these areas.

11/00949 The assessment of renewable energy planning on CO_2 abatement in South Korea
Jun, S. *et al. Renewable Energy*, 2010, 35, (2), 471–477.
Sources of renewable energies (for example, landfill gas, wind and solar energy) are environmentally friendly and electric power generation in South Korea has concentrated on new and renewable energy technologies. The purpose of this paper is to study the economic and environmental influence of renewable energies on existing electricity generation market of South Korea with a energy-economic model called 'long-range energy alternative planning system' and the associated 'technology and environmental database'. A business-as-usual scenario was based on energy supply planning with an existing power plant. And then, the alternative scenarios were considered, namely the base case with existing electricity facilities, the installation plan of different renewable energy facilities, technological improvement and process dispatch rule according to merit order change. In each alternative scenario analysis, alternation trend of existing electricity generation facilities is analysed and the cost of installed renewable energy plants and carbon dioxide reduction potential was assessed quantitatively.

11/00950 The impact of sustainability criteria on the costs and potentials of bioenergy production – applied for case studies in Brazil and Ukraine
Smeets, E. M. W. and Faaij, A. P. C. *Biomass and Bioenergy*, 2010, 34, (3), 319–333.
The goal of this paper is to analyse the impact of the implementation of a certification system on the management system (costs) of and the availability of land (quantity) for bioenergy production. Twelve socio-economic areas of concern (food supply, child labour, (minimum) wages, employment, health care and education) and environmental areas of concern (soil erosion, depletion of fresh water resources, nutrient losses and soil nutrient depletion, pollution from chemicals and biodiversity) are included. Since there is no generally accepted definition of sustainability, a loose and strict set of criteria are defined. Short rotation coppice (SRC) production systems in Ukraine and south-east Brazil in 2015 are taken as case studies. The results indicate that it seems feasible to produce biomass for energy purposes at reasonable cost levels and meeting strict sustainability criteria at the same time. The loose set of criteria has no impact on the costs of energy crop production, which are calculated to be $1.7\,€\,GJ^{-1}$ in Brazil and $2.1\,€\,GJ^{-1}$ in Ukraine. The strict set of criteria results in an increase of the costs of energy crop production by 42% in Brazil and 14% in Ukraine. In general, compliance with strict socio-economic criteria has a limited impact on the costs, because SRC is relatively labour extensive. Strict environmental criteria likely have a larger impact.

11/00951 The impact on Chinese economic growth and energy consumption of the global financial crisis: an input–output analysis
Yuan, C. *et al. Energy*, 2010, 35, (4), 1805–1812.
The dependence on foreign trade increased sharply in China, and therefore the Chinese economy is obviously export-oriented. The global financial crisis will impact the Chinese economic growth violently. The Chinese government adopted some effective measures to fight against the global financial crisis. The most important measure is the 4 trillion Yuan ($586 billion) stimulus plan that was announced on 9 November, 2008. This paper discusses the influence on energy consumption and economic growth of the global financial crisis and the stimulus plan against it by input–output analysis. The results show that the fall of exports caused by the global financial crisis will lead to a decrease of 7.33% in GDP (gross domestic production) and a reduction of 9.21% in energy consumption; the stimulus plan against the global financial crisis will lead to an increase of 4.43% in economic growth and an increase of 1.83% in energy consumption. In the global financial crisis, energy consumption per unit GDP will fall in China.

11/00952 Why did China's energy intensity increase during 1998–2006: decomposition and policy analysis
Zhao, X. *et al. Energy Policy*, 2010, 38, (3), 1379–1388.
Despite the fact that China's energy intensity has continuously decreased during the 1980s and mostly 1990s, the decreasing trend has reversed since 1998 and the past few years have witnessed rapid increase in China's energy intensity. An index decomposition analysis was conducted to identify the key forces behind the increase. It was found that: (1) the high energy demand in industrial sectors is mainly attributed to expansion of production scale, especially in energy-intensive industries; (2) energy saving mainly comes from efficiency improvement, with energy-intensive sectors making the largest contribution; and (3) a heavier industrial structure also contributes to the increase. This study also makes the first attempt to bridge the quantitative decomposition analysis with qualitative policy analyses and fill the gap between decomposition results and policy relevance in previous work. It is argued that: (1) energy efficiency improvement in energy-intensive sectors is mainly due to the industrial policies that have been implemented in the past few years; (2) low energy prices have directly contributed to high industrial energy consumption and indirectly to the heavy industrial structure. Policy suggestions are also provided.

Energy conservation

11/00953 An ETTV-based approach to improving the energy performance of commercial buildings
Chua, K. J. and Chou, S. K. *Energy and Buildings*, 2010, 42, (4), 491–499.
This paper aims to study the various parameters that affect the energy performance of commercial buildings in Singapore. The parameters are diverse, ranging from characteristics of construction of the walls and windows, to the various system settings and types within the building. Building energy performance is measured via two key indexes, namely, the envelope thermal transfer value (ETTV) and the annual cooling energy requirement (E_c). Parameters related to these two indexes are identified. An additional parameter, the solar absorptance of the wall, is further incorporated to calibrate the ETTV equation. A relative ranking on the functional parameters of ETTV has been performed to evaluate their effectiveness in lowering the ETTV of buildings. In addition, the impact of using cladding on ETTV is also studied. A correlation for E_c, expressed in the form of a simple linear equation, has been developed. This correlation accounts for the internal building loads, envelope loads, operating schedules and efficiency of the cooling equipment. Finally, ETTV and E_c have been employed to study the effects of chiller over-sizing and ventilation rates on building cooling energy. In the pursuit for better energy-efficient buildings, the approach presented in this paper contributes to the construct of sustainable energy-efficient built-environment.

11/00954 An optimization planning technique for Suez Canal Network in Egypt
Abou El-Ela, A. A. *et al. Electric Power Systems Research*, 2010, 80, (2), 196–203.
This paper introduces a proposed optimization technique (POT) for predicting the peak load demand and planning of transmission line systems. Many of traditional methods have been presented for long-term load forecasting of electrical power systems. But, the results of these methods are approximated. Therefore, the artificial neural network (ANN) technique for long-term peak load forecasting is modified and discussed as a modern technique in long-term load forecasting. The modified technique is applied on the Egyptian electrical network dependent on its historical data to predict the electrical peak load demand forecasting up to year 2017. This technique is compared with extrapolation of trend curves as a traditional method. The POT is applied also to obtain the optimal planning of transmission lines for the 220 kV of Suez Canal Network (SCN) using the ANN technique. The minimization of the transmission network costs are considered as an objective function, while the transmission lines planning constraints are satisfied. Zafarana site on the Red Sea coast is considered as an optimal site for installing big wind farm units in Egypt. So, the POT is applied to plan both the peak load and the electrical transmission of SCN with and without considering a wind farm to develop the impact of wind farm units on the electrical transmission system of Egypt, considering the reliability constraints which were taken as a separate model in the previous techniques. The application on SCN shows the capability and the efficiently of the proposed techniques to obtain the predicting peak load demand and the optimal planning of transmission lines of SCN up to year 2017.

11/00955 Assessment of energy savings from the revised building energy code of Thailand
Chirarattananon, S. *et al. Energy*, 2010, 35, (4), 1741–1753.
The government of Thailand legislated an Energy Conservation Promotion Act (ECP Act) in 1992 and set by-laws that identify designated buildings (DBs) and detail mandatory requirements for energy conservation for DBs in 1995. An Energy Conservation Promotion Fund (ENCON Fund) was also created to fund energy audits on 1900 DBs. Recently the requirements and procedures for energy conservation in buildings have been revised where system performance requirements for building envelope, lighting, air-conditioning, and hot water generation are adopted. Moreover, the new building energy code (BEC) distinguishes different categories of DBs, provides credit for use of solar energy, and introduces a new option of whole building energy compliance. The authors develop building models from data obtained from energy audit reports and use them to estimate savings on energy and peak demand from future new buildings using forecasted energy and peak demand data from the Load Forecast Subcommittee, a panel tasked to forecast future electric load of Thailand. From a modest level of energy saving in the first year that the code is expected to be enforced, the level of saving rise to over 10% and 20% annually of requirement of target buildings in 6 and 12 years respectively.

11/00956 Carbon print studies for the energy conservation regulations of the UK and China
Wang, N. *et al. Energy and Buildings*, 2010, 42, (5), 695–698.
The recently published building energy conservation regulation of China (GB50189–2005, 2005) was compared with the latest UK building energy conservation regulation (Part L) (Building Regulation Approved Document L2A, 2006). The UK regulation appeared stricter in its requirements and standards than the Chinese regulation. In two case studies, the design of a sample building is altered to fulfil the minimum requirements of the two regulations. The energy consumption and Carbon print of the virtual building under the two set of regulations are estimated by computer based models in the two case studies based on a building in the Cold regions. The building under the UK regulation showed higher energy efficiency and less carbon emissions per year. The high level estimate in the case studies discovered a potential energy savings of 29% by strengthening the design requirements in the Chinese regulation to the UK level. The improvement on energy efficiency of buildings can be achieved in strengthening the proactive design aspects on building envelope, efficient HVAC, lighting and lighting control system. The software used was SBEM which is the default tool in the UK Part L regulation.

11/00957 Comparative analysis of performance and techno-economics for a H_2O–NH_3–H_2 absorption refrigerator driven by different energy sources
Abdullah, M. O. and Hieng, T. C. *Applied Energy*, 2010, 87, (5), 1535–1545.
This study has two objectives. First, it evaluates the transient temperature performance of the H_2O–NH_3–H_2 absorption cooling machine system's components under two types of energy sources, i.e. the conventional electric energy from grid (electric) and fuel energy from liquid petroleum gas (LPG). Results obtained have shown that performance of various components under different type of energy sources is almost coherent. For the evaporator, the system with electric supply has shorter starting time, around 6 min earlier than the system run with LPG. Meanwhile, the system powered by LPG produced a lower cooling temperature around −9 °C, compared to the system run with electric which produced temperature at around −7 °C. Economical study had been carried out subsequently, for three different energy sources, i.e. electric, LPG and solar energy (photovoltaic). From the techno-economical analyses, it was found that the conventional electric

from grid is still the best form of energy source for short-term application, as far as the present location and conditions are concerned. LPG is the next attractive energy source, especially at locations with constant LPG supply; the photovoltaic energy from solar is attractive for long term consideration since it has zero fuel cost and environmentally-friendly, but with the highest initial cost.

11/00958 Economic dispatch of chiller plant by gradient method for saving energy

Chang, Y.-C. *et al. Applied Energy*, 2010, 87, (4), 1096–1101.

This study employs gradient method (GM) to solve economic dispatch of chiller plant problem. GM overcomes the flaw that with the Lagrangian multiplier method the system may not converge at low demand. In this study, the load balance constraint and the operating limit constraints of the chillers are fully accounted for. After analysis and comparison of the two cases studies, it can be said with confidence that this method not only solves the problem of convergence, but also produces results with high accuracy within a rapid timeframe. It can be perfectly applied to the operation of air-conditioning systems.

11/00959 Energy efficiency comparison of forced-air versus resistance heating devices for perioperative hypothermia management

Bayazi, Y. and Sparrow, E. M. *Energy*, 2010, 35, (3), 1211–1215.

Hypothermia is a state in which the temperature of a human body is below the normal temperature, with the onset of the hypothermic state commonly regarded as 36 °C. This state may be encountered due to exposure to a very cold environment in the outdoors or, surprisingly, in a hospital operating room. In the latter situation, the diminution of metabolic heat generation, coupled with moderate temperatures in the surroundings and absence of a covering over the afflicted parts of the body, creates the possibility of hypothermia. There are several available devices that are designed to ward off the onset of hypothermia. These currently most frequently used devices can be placed in two categories: (a) convective air warming and (b) direct-contact heat conduction. The warming principles that underlie these two approaches are distinctly different. Furthermore, the energy efficiencies of the two approaches differ significantly. The energy penalty which results from these different efficiencies may be compounded by the fact that the portion of the input energies to these devices which escapes into the operating room ambient must be extracted to maintain a comfortable temperature for the surgical staff. Since energy-extracting equipments such as air-conditioning machines are far from being perfectly efficient, the heat-extraction process also introduces wasted energy. Experiments were performed to determine the energy-utilization efficiencies of the representative devices in the two categories cited above. This information, taken together with the known efficiencies of air-conditioning machines, enabled an overall efficiency encompassing both the therapeutic device and the heat-extraction device to be calculated. The experimental data revealed that the specifics of individual devices within a category played a larger role with regard to energy efficiency than did the category itself.

11/00960 Energy efficiency of a dynamic glazing system

Lollini, R. *et al. Solar Energy*, 2010, 84, (4), 526–537.

The reduction of air-conditioning energy consumptions is one of the main indicators to act on when improving the energy efficiency in buildings. In the case of advanced technological buildings, a meaningful contribution to the thermal loads and the energy consumptions reduction could depend on the correct configuration and management of the envelope systems. In recent years, the architectural trend toward highly transparent all-glass buildings presents a unique challenge and opportunity to advance the market for emerging, smart, dynamic window and dimmable daylighting control technologies. A prototype dynamic glazing system was developed and tested at ITC-CNR; it is aimed at actively responding to the external environmental loads. Both an experimental campaign and analyses by theoretical models were carried out, aimed at evaluating the possible configurations depending on different weather conditions in several possible places. Therefore, the analytical models of the building-plant system were defined by using a dynamic energy simulation software (EnergyPlus). The variables that determine the system performance, also influenced by the boundary conditions, were analysed, such as *U*- and *g*-value; they concern both the morphology of the envelope system, such as dimensions, shading and glazing type, gap airflow thickness, in-gap airflow rate, and management, in terms of control algorithm parameters tuning fan and shading systems, as a function of the weather conditions. The configuration able to provide the best performances was finally identified by also assessing such performances, integrating the dynamic system in several building types and under different weather conditions. The dynamic envelope system prototype has become a commercial product with some applications in façade systems, curtain walls and windows. The paper describes the methodological approach to prototype development and the main results obtained, including simulations of possible applications on real buildings.

11/00961 Evaluation of energy performance indicators and financial aspects of energy saving techniques in residential real estate

Entrop, A. G. *et al. Energy and Buildings*, 2010, 42, (5), 618–629.

The energy consumption in the existing residential building stock accounts for about 40% of the total energy consumption in the built environment. Different types of energy performance indicators to assess the energy consumption of buildings were and still are internationally under development. This paper compared the methodologies and accuracies of three Dutch energy performance indicators by applying them to eight houses. This application shows that the actual domestic energy use is linearly correlated with the estimated energy consumption given by the energy performance indicators, but 7–25% lower. Based on the energy performance indicators and actual energy use, this methodology is able to incorporate additional revenues within the financial analysis of energy saving techniques. These revenues are related to the value of the dwelling in which the techniques are installed. The same houses were also used to analyse the financial returns on energy saving investments. By assigning the value increase of real estate to two popular specific energy saving techniques, namely wall and roof insulation, it is found that the payback period could be 40–50% shorter than when it is solely based on investment costs and energy prices.

11/00962 Evaluation of the economic feasibility for the recycling of construction and demolition waste in China – the case of Chongqing

Zhao, W. *et al. Resources, Conservation and Recycling*, 2010, 54, (6), 377–389.

In the recycling chain of construction and demolition waste, it is impossible to guarantee a certain quality of recycled products and to recycle a large amount of materials in recycling centres without mechanical sorting facilities. This counts even more when the produced materials have a low economic value, as is the case with crushed and cleaned debris, also called aggregates. In order to assess if recycling can be done effectively, a feasibility study of the recycling of construction and demolition (C&D) waste is necessary. In the paper, the economic feasibility of recycling facilities for C&D waste in China's Chongqing city was assessed. Investigations on the current situation of C&D waste recycling in Chongqing showed that there were a large quantity of waste and an enormous demand for recycled materials due to the busy ongoing construction activities, which generated a large market potential and also brought a challenge to the strengthening of the recycling sector. However, a full cost calculation and an investment analysis showed that, under current market conditions, operating C&D waste recycling centres in Chongqing might face high investment risks. Thus, the regulations and economic instruments like tax that can support the economic feasibility of recycling are discussed, and the recommendations for the choice of instruments are provided.

11/00963 Evaluation of the effectiveness of an energy efficiency program for new home construction in eastern North Carolina

Dixon, G. *et al. Energy*, 2010, 35, (3), 1491–1496.

This paper reports on the evaluation of the effectiveness of an energy efficiency programme in eastern North Carolina, USA. This programme is focused on improved construction methods for residential housing. The programme incorporates proven energy-saving technologies, construction procedures, onsite inspections, and design construction methodologies in new residential construction. The analysis compared the energy usage associated with the houses built in conjunction with the energy efficiency programme (test group) with similar new residential construction unrelated to the programme (control group). Several statistical methods were employed to establish differences between the energy efficiency programme participants and the control group. The analysis provides significant support for the effectiveness of this energy efficiency programme and supports the suitability of similar efforts for inclusion in plans for renewable energy offsets and energy efficiency standards.

11/00964 Impacts of the shading-type building-integrated photovoltaic claddings on electricity generation and cooling load component through shaded windows

Sun, L. L. and Yang, X. H. *Energy and Buildings*, 2010, 42, (4), 455–460.

The shading-type building-integrated photovoltaic (BIPV) claddings can act as power generators as well as external shading devices of a building, which reduce the energy consumption of the building. However, there is little information about energy impacts of different tilt angles of the shading-type BIPV claddings. By considering the typical meteorological conditions of Hong Kong, the energy perform-

ance of the shading-type BIPV claddings, in terms of the electricity generation and the cooling load reduction, is analysed in this paper. The optimum tilt angle of PV modules for maximum electricity generation is found to be 20° instead of local latitude. Combining electricity generation and cooling load reduction, it can be concluded that the optimum tilt angles for the first type of the shading-type BIPV claddings vary from 30° to 50°, while the optimum tilt angle for the second type is 0°.

11/00965 Integration of post-combustion capture and storage into a pulverized coal-fired power plant

Sanpasertparnich, T. *et al. International Journal of Greenhouse Gas Control*, 2010, 4, (3), 499–510.

Post-combustion CO_2 capture and storage (CCS) presents a promising strategy to capture, compress, transport and store CO_2 from a high volume–low pressure flue gas stream emitted from a fossil fuel-fired power plant. This work undertakes the simulation of CO_2 capture and compression integration into an 800 MW_e supercritical coal-fired power plant using chemical process simulators. The focus is not only on the simulation of full load of flue gas stream into the CO_2 capture and compression, but also, on the impact of a partial load. The result reveals that the energy penalty of a low capture efficiency, for example, at 50% capture efficiency with 10% flue gas load is higher than for 90% flue gas load at the equivalent capture efficiency by about 440 kWh_e/tonne CO_2. The study also addresses the effect of CO_2 capture performance by different coal ranks. It is found that lignite pulverized coal (PC)-fired power plant has a higher energy requirement than subbituminous and bituminous PC-fired power plants by 40.1 and 98.6 MW_e, respectively. In addition to the investigation of energy requirement, other significant parameters including energy penalty, plant efficiency, amine flow rate and extracted steam flow rate, are also presented. The study reveals that operating at partial load, for example at half load with 90% CO_2 capture efficiency, as compared with full load, reduces the energy penalty, plant efficiency drop, amine flow rate and extracted steam flow rate by 9.9%, 24.4%, 50.0% and 49.9%, respectively. In addition, the effect of steam extracted from different locations from a series of steam turbine with the objective to achieve the lowest possible energy penalty is evaluated. The simulation shows that a low extracted steam pressure from a series of steam turbines, for example at 300 kPa, minimizes the energy penalty by up to 25.3%.

11/00966 Minimizing lighting power density in office rooms equipped with anidolic daylighting systems

Linhart, F. and Scartezzini, L. *Solar Energy*, 2010, 84, (4), 587–595.

Electric lighting is responsible for up to one third of an office building's electricity needs. Making daylight more available in office buildings can not only contribute to significant energy savings but also enhance the occupants' performance and wellbeing. Anidolic daylighting systems (ADS) are one type of very effective façade-integrated daylighting systems. All south-facing office rooms within the LESO solar experimental building in Lausanne (Switzerland) are equipped with a given type of ADS. A recent study has shown that these offices' occupants are highly satisfied with their lighting environment. The most energy-efficient south-facing offices have a lighting power density of less than 5 W/m^2. The lighting situation within these 'best practice'-offices has been assessed using the lighting simulation software RELUX Vision. Because this lighting situation is very much appreciated by the occupants, it was used as a starting point for developing even more energy-efficient office lighting designs. Two new lighting designs, leading to lighting power densities of 3.9 W/m^2 and 3 W/m^2, respectively, have been suggested and simulated with RELUX Vision. Simulation results have shown that the expected performances of these new systems are comparable to that of the current lighting installation within the 'best practice'-offices or even better. These simulation results have been confirmed during experiments on 20 human subjects in a test office room recently set up within the LESO building. This article gives engineers, architects and light planers valuable information and ideas on how to design energy-efficient and comfortable electric lighting systems in office rooms with abundant access to daylight.

11/00967 Optimisation of buildings' solar irradiation availability

Kämpf, J. H. *et al. Solar Energy*, 2010, 84, (4), 596–603.

In order to improve the sustainability of new and existing urban settlements it is desirable to maximize the utilization of the solar energy incident on the building envelope, whether by passive or active means. To this end the authors have coupled a multi-objective optimization algorithm with the backwards ray tracing program RADIANCE which itself uses a cumulative sky model for the computation of incident irradiation (Wh/m^2) in a single simulation. The parameters to optimize are geometric (the height of buildings up to their facade and the height and orientation of roofs), but with the constraint of maintaining an overall built volume, and the objective function is heating season solar irradiation offset by envelope heat losses. This methodology has been applied to a range of urban typologies and produces readily interpretable results. The focus of this work is on the design of new urban forms but the method could equally be applied to examine the relative efficiency of existing urban settlements, by comparison of existing forms with the calculated optima derived from relevant specifications of the building envelope.

11/00968 Proposal of technical constructive obligations to reduce the summer energetic consumptions

Barelli, L. *et al. Energy and Buildings*, 2010, 42, (4), 401–411.

The continual increase of fuel consumption and costs, which is affecting many European countries, has provoked a notable interest, also from a legislative point of view. To this aim, particular attention must be paid to the building cooling: in the summer, in fact, there is a great demand of indoor comfort with consequent increase of energy for air-conditioning, which is nowadays significant in relation to the heating requirement. In this context, the object of the present work is the development of new technical constructive standards to limit the energy needs of new buildings or in the case of significant renovation, specifically for the summer season. The study was carried out in reference to Italy, as the particular case-study, providing in any case a general methodology which can be applied to other European countries on the basis of the characteristic climate data. Moreover, the standards system developed for Italy was tested on actual cases; with particular reference to the solar factor limit tables, significant benefits result in terms of reducing the energy use for the summer-time cooling. Less remarkable, instead, are the benefits which can derive from the application of the limits imposed for the absorption coefficient of the opaque structures.

11/00969 Reducing power consumption in multi-compressor refrigeration systems

Widell, K. N. and Eikevik, T. *International Journal of Refrigeration*, 2010, 33, (1), 88–94.

An experimental analysis of compressor operation in a large refrigeration system was undertaken and a model for optimal compressor operation for energy efficiency was developed. The system used 5 screw compressors and ammonia as the refrigerant, with slide valves to regulate the compressors and match their refrigeration capacity with product freezing loads. Compressors in the existing system can operate simultaneously with reduced capacities, which results in reduced energy efficiency. Optimized operation was made both with and without a variable frequency drive. The results showed that the most electrical energy can be saved during days when not all of the tunnels were loaded. It is assumed that € 30 000–50 000 can be saved per year by optimizing the operation of the refrigeration system.

11/00970 Scoping the potential of monitoring and control technologies to reduce energy use in homes

Meyers, R. J. *et al. Energy and Buildings*, 2010, 42, (5), 563–569.

This scoping study takes a broad look at how information technology-enabled monitoring and control systems could assist in mitigating energy use in residences by more efficiently allocating the delivery of services by time and location. A great deal of energy is wasted in delivering services inefficiently to residents such as heating or cooling unoccupied spaces, overheating/undercooling for whole-house comfort, leakage current, and inefficient appliances. A framework was constructed to estimate different categories of inefficient energy services and the result of this initial estimate was that over 39% of residential primary energy is wasted. How monitoring and control technologies could manage home energy use to reduce waste was then considered. Technologies considered here included programmable thermostats, smart meters and outlets, zone heating, automated sensors, and wireless communications infrastructures. The level of energy services delivered was assumed to remain unchanged, with all energy savings being realized through better management. A final discussion on barriers to adoption of these systems speculated that a lack of consumer awareness of the technologies, high costs due to lack of economies of scale, and difficult user interfaces are currently the major hurdles toward adoption.

11/00971 Simulation and electricity savings estimation of air-cooled centrifugal chiller system with mist pre-cooling

Yu, F. W. and Chan, K. T. *Applied Energy*, 2010, 87, (4), 1198–1206.

This paper analyses how to apply mist pre-cooling coupled with condensing temperature control to enhance the coefficient of performance (COP) of an air-cooled chiller system and hence achieve electricity savings. A modified DOE-2.1E chiller model was developed to predict the change of chiller COP due to various set points of condensing temperature and pre-cooling of air stream entering the condenser. The model was calibrated by using manufacturer's data and used to estimate the annual electricity consumption of a chiller system serving an office building under four operating schemes: traditional head pressure control (HPC); HPC with a fixed mist generation rate; condensing temperature control (CTC) with a fixed mist generation

rate; CTC with an optimal mist generation rate. It was estimated that using optimal mist control with CTC could achieve a 19.84% reduction in the annual electricity consumption of the system. Considerations when using mist pre-cooling to maximize electricity savings have been discussed.

11/00972 Study on the heat transfer of high-vacuum-multilayer-insulation tank after sudden, catastrophic loss of insulating vacuum
Xie, G. F. *et al. Cryogenics*, 2010, 50, (10), 682–687.
One of the most serious accidents that can occur in a high-vacuum-multilayer-insulation (HVMLI) cryogenic tank is a sudden, catastrophic loss of insulating vacuum (SCLIV). There is no doubt that the gases leaking into the insulation jacket have some influence on its heat transfer process. However, this issue has not been thoroughly studied so far. In this paper, a test rig was built and experiments were conducted using a SCLIV cryogenic tank and with nitrogen, helium and air. The venting rates of the tank and temperature in the insulation jacket were measured after the three different gases leaking into the jacket. A heat-transfer model describing the heat-transfer process of a SCLIV tank was also presented. The calculated results using this model were compared against the experimental data. It is found that the heat-transfer performance of the HVMLI cryogenic tank after SCLIV is strong relevant to the type of gas leaking into the insulation jacket.

11/00973 The case study of furnace use and energy conservation in iron and steel industry
Chan, D. Y.-L. *et al. Energy*, 2010, 35, (4), 1665–1670.
This work was performed on-site energy audits of 118 firms in the Taiwanese iron and steel industry during 2000–2008. It was found that the total potential energy savings was estimated about 79,160.8 kL of crude oil equivalent. It was identified to generate potential electricity savings of 170,322.8 MWH, fuel oil savings of 22,235.1 kL, steam coal savings of 4922 tons, and natural gas savings of 10,735,000 cubic metres. It was represented a total reduction of 217,866.5 tons in carbon dioxide emissions, equivalent to the annual carbon dioxide absorption capacity of a 5836 ha plantation forest. This study has established a national database presenting information and energy saving methods for energy users and has identified the potential areas for making energy savings to provide a energy conservation reference. It can assist the energy users in performing energy audits and increasing energy utilization efficiency.

11/00974 The devil is in the details: household electricity saving behavior and the role of information
Ek, K. and Söderholm, P. *Energy Policy*, 2010, 38, (3), 1578–1587.
The purpose of this paper is to analyse Swedish households' willingness to increase their daily efforts to save electricity. The analysis builds on a broad theoretical framework, which embraces both economic and norm-based motivations in explaining household behaviour. The paper pays particular attention to the role of information about the availability of different behavioural changes that can be undertaken at the household level. The empirical results are based on a postal survey that was sent out to 1200 Swedish households, and the econometric analysis is carried out within a so-called ordered probit framework. The results indicate that costs, environmental attitudes and social interactions are all important determinants of electricity saving activities within Swedish households. The authors tested the hypothesis that information about available savings measures that is presented in a more concrete and specific way is more likely to affect (stated) behaviour than is more general information, and the data collected support this notion. The paper ends by discussing some implications of these results for the design of future informative policy measures in the energy-efficiency field.

11/00975 The impact of informational feedback on energy consumption – a survey of the experimental evidence
Faruqui, A. *et al. Energy*, 2010, 35, (4), 1598–1608.
In theory, in-home displays (IHDs) can revolutionize the way utilities communicate information to customers because they can induce changes in customer behaviour even when they are not accompanied by a change in electric prices or rebates for purchasing efficient equipment. IHDs provide consumers with direct feedback – real-time information on energy consumption and costs – and turn a once opaque and static electric bill into a transparent, dynamic, and controllable process. However, to what extent do consumers actually respond to the direct feedback provided by IHDs? This studied reviewed a dozen utility pilot programs in North America and abroad that focus on the energy conservation impact of IHDs. Also reviewed were overall customer opinions and attitudes towards IHDs and direct feedback to the extent that this information is available from the pilot studies. This review indicates that the direct feedback provided by IHDs encourages consumers to make more efficient use of energy. It was found that consumers who actively use an IHD can reduce their consumption of electricity on average by about 7% when prepayment of electricity is not involved. When consumers both use an IHD and are on an electricity prepayment system, they can reduce their electricity consumption by about twice that amount. In regard to demand response impacts, it was found that the impact of time-of-use rates is augmented by direct feedback from IHDs.

11/00976 Thermal analysis of a new concept in a household clothes tumbler dryer
Bansal, P. *et al. Applied Energy*, 2010, 87, (5), 1562–1571.
This paper presents a theoretical and experimental study of a novel water heat exchanger that heats the air in a domestic clothes tumbler dryer in place of a traditional electric heater, with a view to improve its energy efficiency. Modelling of a waste heat recovery heat exchanger has been undertaken using EES software package to assess its effectiveness on the drying cycle. The new dryer was found to have shorter drying times, better moisture extraction rates for the same power input and hence more efficient than the traditional dryer.

17 ENERGY CONVERSION AND RECYCLING

11/00977 An innovative modularity of heat circulation for fractional distillation
Kansha, Y. *et al. Chemical Engineering Science*, 2010, 65, (1), 330–334.
A novel modularity of heat circulation for distillation process, which reduces the energy consumption, is proposed. By incorporating compressors and heat exchangers, the heat of the distillate is recuperated and exchanged with the heat of the feed streams. The proposed technology achieves a reduction in the required energy of more than 75% compared to a benchmark process that uses an external heat source for heating. This shows that the proposed modularity of heat circulation for distillation process is a very promising technology to reduce energy demand for distillation drastically.

11/00978 Combustible gas production (methane) and biodegradation of solid and liquid mixtures of meat industry wastes
Marcos, A. *et al. Applied Energy*, 2010, 87, (5), 1729–1735.
This work determines the optimal operational conditions on the methane production as well as on the biodegradation obtained from the anaerobic codigestion of solid (fat, intestines, rumen, bowels, whiskers, etc.) and liquid (blood, washing water, manure, etc.) wastes of meat industry, particularly the ones rising from the municipal slaughterhouse of Badajoz (Spain). The experiments were performed using a 2 litre capacity discontinuous digester at 38 °C. The loading rate were 0.5, 1, 2, 3, and 4.5 g COD for wastewater (washing water and blood; Mixture 1), and 0.5, 1, 2, 3, and 4 g COD for the co-digestion of a mixture of 97% liquid effluent and 3% solid wastes v/v (Mixture 2) which represents the annual mean composition of the waste generated by the slaughterhouse. The maximal biodegradation rates obtained were: Mixture 1, 56.9% for a COD load of 1 g; and Mixture 2, 19.1% for a COD load of 2 g. For both mixtures, the greatest methane production was for the maximum COD load (4.5 g for Mixture 1, and 4 g for Mixture 2), at which values the amounts of methane obtained during and at the end of the co-digestion were practically indistinguishable between the two mixtures. The results will be used to design, construct, and establish the optimal operating conditions of a continuous complete-mixture biodigester.

11/00979 Production of innovative, recycled and high-performance asphalt for road pavements
Celauro, C. *et al. Resources, Conservation and Recycling*, 2010, 54, (6), 337–347.
This paper deals with a specific laboratory study aiming at perfecting recycled asphalt with high mechanical performance, for surface and structural layers of flexible pavements. The aim of the research was to combine in the same material the maximum possible quantity of recycled asphalt, coming from degraded asphalt layers, together with high structural performance of the recycled mixtures obtained (mainly stability, load spreading properties, rutting and fatigue resistance) that should not be lower, or possibly better than those offered by traditional asphalt mixture, made with virgin binder and aggregate. For this purpose, innovative recycled mixtures, close-graded and with high mechanical performance, characterized by high content of recycled asphalt (up to 50%) and designed for surface, binder and base layers were investigated in a laboratory study. The results of physical and mechanical characterization tests show that, by controlling the homogeneity of recycled material and by using new bitumen with adequate rheological properties, it is possible to obtain paving mixtures

with high content of recycled materials that, in relation to their intended use (surface, binder or base layer), can be considered as 'high-performance mixtures'.

11/00980 Prospective framework for collection and exploitation of waste cooking oil as feedstock for energy conversion

Singhabhandhu, A. and Tezuka, T. *Energy*, 2010, 35, (4), 1839–1847.

From the viewpoint of waste-to-energy, waste cooking oil is one of the attractive and available recycled feedstocks, apart from agricultural residues. The generation of energy from waste cooking oil is considered as an effective technique for waste management, as well as a beneficial form of energy recovery. Two alternative systems and a conventional system of waste cooking oil collection and conversion are evaluated by the cost benefit analysis in order to find a suitable method for waste-to-energy conversion. The results show that the collection of waste cooking oil with waste lubricating oil (System II) a useful alternative to the management of waste cooking oil ($B/C > 1$). The total heat produced by the combustion of pyrolytic oil at maximum and minimum conversion rates is also determined. The separate collection of waste cooking oil, subjected to chemical pre-treatment prior to introduction in a pyrolysis reactor (System III), is considered an undesirable option ($B/C < 1$) due to the cost of the chemicals involved. Although the exclusion of chemical pre-treatment makes System III a desirable option, the total amount of heat of combustion generated is less. The increased electricity cost required for the process has no effect on the benefit-cost ratio of System II. However, System III, excluding chemical pre-treatment, becomes an unprofitable alternative when the electricity cost reaches 100% of the fixed capital cost at the minimum conversion rate.

11/00981 Reduction of energy cost and CO_2 emission for the furnace using energy recovered from waste tail-gas

Jou, C.-J. G. *et al. Energy*, 2010, 35, (3), 1232–1236.

In this research, the waste tail gas emitted from petrochemical processes, e.g. catalytic reforming unit, catalytic cracking unit and residue desulfurization unit, was recovered and reused as a replacement of natural gas. On-site experimental results show that both the flame length and orange-yellowish brightness decrease with more proportion of waste gas fuel added to the natural gas, and that the adiabatic temperature of the mixed fuel is greater than 1800 °C. A complete replacement of natural gas by the recovered waste gas fuel will save 5.8×10^6 m^3 of natural gas consumption, and 3.5×10^4 tons of CO_2 emission annually. In addition, the reduction of residual O_2 concentration in flue gases from 4% to 3% will save 1.1×10^6 m^3 of natural gas consumption, reduce 43.0% of NO_x emission, and 1.3×10^3 tons of CO_2 emission annually. Thus, from the viewpoint of the overall economics and sustainable energy policy, recovering the waste tail gas energy as an independent fuel source to replace natural gas is of great importance for saving energy, reducing CO_2 emission reduction, and lowering environmental impact.

11/00982 The influence of water and steam injection on the performance of a recuperated cycle microturbine for combined heat and power application

Lee, J. J. *et al. Applied Energy*, 2010, 87, (4), 1307–1316.

Microturbines are promising power sources for small scale combined heat and power (CHP) systems. However, the power output and efficiency of microturbines decreases much as the ambient temperature increases. As a remedy to minimize the performance penalty at hot ambient conditions, the injection of water or steam into a microturbine CHP system was analysed in this work. An analysis program to simulate the operation of a microturbine CHP system was set up and validated by using measured test data. The injection of hot water, which is generated at the heat recovery unit, at two different locations inside the microturbine was predicted. The generation of steam through the same heat recovery unit and its injection at the two locations was predicted as well. All the four cases provide sufficiently enhanced power output. Injection at the recuperator inlet exhibits a higher efficiency than injection at the combustor in both water and steam injections. Steam injection provides a higher power generation efficiency than water injection on the average. The injection of steam at the recuperator inlet is most promising in terms of power generation efficiency. However, water injection at the recuperator also enhances power generation efficiency while still providing thermal energy to some extent.

11/00983 Thermolysis of waste plastics to liquid fuel: a suitable method for plastic waste management and manufacture of value added products – a world prospective

Panda, A. K. *et al. Renewable and Sustainable Energy Reviews*, 2010, 14, (1), 233–248.

Plastics have been one of the materials with the fastest growth because of their wide range of applications due to versatility and relatively low cost. Since the duration of life of plastic products is relatively small, there is a vast plastics waste stream creating a serious environmental problem. Again, because disposal of post-consumer plastics is increasingly being constrained by legislation and escalating costs, there is considerable demand for alternatives to disposal or land filling. Advanced research in the field of green chemistry could yield biodegradable/green polymers but is currently too limited to substitute the non-biodegradable plastics in different applications. Once standards are developed for degradable plastics they can be used to evaluate the specific formulations of materials which will find best application in this state as regards their performance and use characteristics. Among the alternatives available are source reduction, reuse, recycling, and recovery of the inherent energy value through waste-to-energy incineration and processed fuel applications. Production of liquid fuel would be a better alternative as the calorific value of the plastics is comparable to that of fuels, around 40 MJ/kg. Each of these options potentially reduces waste and conserves natural resources. Plastics recycling, continues to progress with a wide range of old and new technologies. Many research projects have been undertaken on chemical recycling of waste plastics to fuel and monomer. This is also reflected by a number of pilot, demonstration, and commercial plants processing various types of plastic wastes in Germany, Japan, USA, India, and elsewhere. Further investigations are required to enhance the generation of value added products (fuel) with low investments without affecting the environment. The paper reviews the available literature in this field of active research and identifies the gaps that need further attention.

11/00984 Using engine exhaust gas as energy source for an absorption refrigeration system

Manzela, A. A. *et al. Applied Energy*, 2010, 87, (4), 1141–1148.

This work presents an experimental study of an ammonia–water absorption refrigeration system using the exhaust of an internal combustion engine as energy source. The exhaust gas energy availability and the impact of the absorption refrigeration system on engine performance, exhaust emissions, and power economy are evaluated. A production automotive engine was tested in a bench test dynamometer, with the absorption refrigeration system adapted to the exhaust pipe. The engine was tested for 25%, 50%, 75% and wide-open throttle valve. The refrigerator reached a steady state temperature between 4 and 13 °C about 3 h after system start up, depending on engine throttle valve opening. The calculated exhaust gas energy availability suggests the cooling capacity can be highly improved for a dedicated system. Exhaust hydrocarbon emissions were higher when the refrigeration system was installed in the engine exhaust, but carbon monoxide emissions were reduced, while carbon dioxide concentration remained practically unaltered.

11/00985 Utilization of waste heat from GT-MHR for power generation in organic Rankine cycles

Yari, M. and Mahmoudi, S. M. S. *Applied Thermal Engineering*, 2010, 30, (4), 366–375.

The gas turbine-modular helium reactor (GT-MHR) is currently being developed by an international consortium. In this power plant, circulating helium that has to be compressed in a single or two successive stages cools the reactor core. For thermodynamic reasons, these compression stages require pre-cooling of the helium to about 26 °C through the use of intercooler and pre-cooler in which water is used to cool the helium. Considerable thermal energy (~300 MWth) is thus dissipated in these components. This thermal energy is then rejected to a heat sink. For different designs, the temperature ranges of the helium in the intercooler and pre-cooler could be about 100 and 150 °C, respectively. These are ideal energy sources to be used in an organic Rankine cycles (ORC) for power generation. This study examines the performance of a gas-cooled nuclear power plant with closed Brayton cycle (CBC) combined with two OCR. More attention was paid to the irreversibilities generated in the combined cycle. Individual models are developed for each component through applications of the first and second laws of thermodynamics. The effects of the turbine inlet temperature, compressor pressure ratio, evaporator temperature and temperature difference in the evaporator on the first- and second-law efficiencies and on the exergy destruction rate of the combined cycle were studied. Finally the combined cycle was optimized thermodynamically using Engineering Equation Solver software. Based on identical operating conditions, a comparison between the GT-MHR/ORC and a simple GT-MHR cycle is also made. It was found that both the first- and second-law efficiencies of GT-MHR/ORC cycle are about 3%-points higher than that of the simple GT-MHR cycle. Also, the exergy destruction rate for GT-MHR/ORC cycle is about 5% lower than that of the GT-MHR cycle.