01 SOLID FUELS

Sources, winning, properties

11/00986 A comparative study on co-combustion performance of municipal solid waste and Indonesian coal with high ash Indian coal: a thermogravimetric analysis

Muthuraman, M. *et al. Fuel Processing Technology*, 2010, 91, (5), 550–558.

In recent years there has been an increasing utilization of coal blends in the Indian power industry, with Indonesian coal, due to high ash content and shortages in domestic coal production. On the other hand, rapid economic growth is aggravating the municipal solid waste (MSW) related environmental problems. In this study, an attempt has been made to compare the co-combustion characteristics of hydrothermally treated MSW and Indonesian coal with high ash Indian coal, so as to replace the Indonesian coal with MSW. The effect of blending Indonesian coal and hydrothermally treated MSW with Indian coal on ignition behaviour was studied. MSW blends of 10%, 20%, 30% and 50% (in wt%), and an Indonesian blend of 10% with Indian coal were tested in a thermogravimetric analyser in the temperature from ambient to 700 °C with a temperature increase of 10 °C/min. From the results, at 10% of blend, ignition and carbon burnout were similar for Indonesian and MSW blend, analogous to coal combustion and even better than the Indonesian coal blend, which indicated the feasibility for replacing Indonesian coal with hydrothermally treated MSW. Further, the results show a scope to increase the MSW blend in Indian coal up to 20%, as the constituents behave as a single fuel.

11/00987 Distribution of inorganic and organic substances in the hydrocyclone separated Slovak sub-bituminous coal

Zubrik, A. *et al. Fuel*, 2010, 89, (8), 2126–2132.

A low-rank Slovak sub-bituminous coal from the Handlová deposit was physically treated by washing in a water-only cyclone with the goal to find the separation effect for inorganic (mainly Fe-bearing minerals) and organic substances (humic acids, diterpanes). A high-quality coal product with the ash content in the dry matter of 9.02% and carbon content of $C^d = 68.12\%$ at a mass yield of 29.51% was obtained using the water-only cyclone processing. At first, the physically treated coal samples were detailed characterized by XRD, ^{57}Fe Mössbauer spectroscopy, FT-IR and HR-TEM. In addition to non-crystalline organic coal components, inorganic compounds belonging to silicate minerals (kaolinite, muscovite and quartz) as well as to Fe-bearing sulfide minerals (pyrite) were identified in the sub-bituminous coal by XRD. ^{57}Fe Mössbauer spectroscopy detected the presence of iron carbonate (siderite), iron-containing clay mineral and two sulfur-containing minerals (pyrite, jarosite) in the untreated coal. On the other hand, only one Fe-bearing mineral, (pyrite) was found in the washed coal. Effect of the physical separation is also demonstrated in FT-IR spectra, where the peak at 1040 cm^{-1} representing the silicate component in the untreated sample is not detectable in the washed coal sample. Presence of extractive organic substances, i.e. humic acids and tetracyclic diterpane (16α(*H*)-phyllocladane), in the hydrocyclone products is also evidenced. It was confirmed that the isolated diterpenoic compound is attendant in the washed product with the lowest ash content and it is assimilated with the organic part of coal. Surprisingly, humic acids were found in the highest concentration in the slurry that has the highest content of ash (63.14%).

11/00988 Occurrence of non-mineral inorganic elements in macerals of low-rank coals

Li, Z. *et al. International Journal of Coal Geology*, 2010, 81, (4), 242–250.

Electron microprobe study of individual macerals in low-rank coals of Permian to Tertiary age from Australia, New Zealand, Indonesia and Thailand has shown that measurable proportions of inorganic elements are consistently found in organic components, especially the vitrinite macerals, in which no minerals or mineral inclusions are visible under the microscope. The vitrinites of such coals have been found to contain up to around 0.5% Al, 1.5% Ca, 0.1% Mg, 0.7% Fe and 0.2% Ti. The Al occurs without measurable proportions of Si, and hence does not represent sub-micron clay minerals within the maceral components. Inertinite macerals in the coals, such as fusinite, typically contain lesser proportions of these elements, and often have no more than background (<0.05%) concentration levels. Except where soluble minerals such as carbonates are also present, the proportion of Ca, Al and Fe indicated from microprobe analysis in the macerals, especially in the vitrinites, is very close to the mobile proportion of the same elements indicated in previous studies from selective leaching techniques. This suggests that the elements occur as an inherent part of the organic structure in the macerals, possibly as a combination of exchangeable ions, carboxylates, chelates and other organometallic compounds; they may also be held by physical absorption and adsorption mechanisms, or may possibly represent inorganic nanoparticles. The proportions of Al, Ca and Fe in the vitrinites of the samples studied decrease with coal rank. Although there are exceptions, these and other non-mineral inorganic elements (Mg, Ti) are also not usually detected by the microprobe in higher rank coals (above 75% carbon in vitrinite or around 0.6% vitrinite reflectance). Their absence is probably a consequence of expulsion from the maceral structures during the progressive aromatization associated with rank advance, by processes such as dehydration, decarboxylation and dehydroxylation.

11/00989 Predicted mineral melt formation by BCURA coal sample bank coals: variation with atmosphere and comparison with reported ash fusion test data

Thompson, D. *Fuel*, 2010, 89, (8), 2062–2071.

The thermodynamic equilibrium phases formed under ash fusion test and excess air combustion conditions by 30 coals of the BCURA coal sample bank have been predicted from 1100 to 2000 K using the MTDATA computational suite and the MTOX database for silicate melts and associated phases. Predicted speciation and degree of melting varied widely from coal to coal. Melting under an ash fusion test atmosphere of $CO_2:H_2$ 1:1 was essentially the same as under excess air combustion conditions for some coals, and markedly different for others. For those ashes which flowed below the fusion test maximum temperature of 1773 K flow coincided with 75–100% melting in most cases. Flow at low predicted melt formation (46%) for one coal cannot be attributed to any one cause. The difference between predicted fusion behaviours under excess air and fusion test atmospheres becomes greater with decreasing silica and alumina, and increasing iron, calcium and alkali metal content in the coal mineral.

11/00990 Study on the liquefaction of Shengli lignite with NaOH/methanol

Lei, Z. *et al. Fuel Processing Technology*, 2010, 91, (7), 783–788.

The behaviour of liquefaction of Shengli (SL) lignite with NaOH–methanol was studied. Based on high content of water in lignite and the economy of the process (amounts of NaOH used), the effects of NaOH concentration, methanol content and water content on the liquefaction behaviour of SL lignite were preliminarily investigated. The results show that SL lignite has a good reaction activity, and its conversion and product yield reach 98% and 99% at 300 °C for 1 h respectively, when the ratio of SL lignite, NaOH and methanol is for 1 g : 1 g : 10 ml. NaOH participates in the reaction. The increase of the amount of NaOH significantly increases the amount of tetrahydrofuran soluble (THFS) fraction. Methanol plays a promotion role in the liquefaction, which makes the product yield increase for about 16–23%. Water content has little effect on the SL lignite conversion, product yield and the product distribution. Solvent-extraction components of liquefaction products of SL lignite with NaOH–methanol are mainly THFS, toluene soluble (TS), hexane soluble (HS) and water soluble fractions (WS). The FTIR analyses of solvent-extraction components show that all of the fractions contain OH group, aromatic structure, carbonyl group and aromatic ether oxygen group.

11/00991 TGA and DMA studies of blends from very good coking Zofiówka coal and various carbon additives: weakly coking coals, industrial coke and carbonized plants

Krzesińska, M. *et al. International Journal of Coal Geology*, 2010, 81, (4), 293–300.

The aim of this work is to study the effects of various carbon additives, blended with very good coking coal, on the thermal decomposition of the blends. The blends possess fixed content (50 wt%) of very good coking coal from the Zofiówka Mine. The remaining components of the blends are worse coking coals collected from the Janina, Krupiński, Szczyglowice, Jas-Mos mines (coals of carbon content ranging from 73 up to 92 wt%), and very porous carbons: coke (from the coking plant Zdzieszowice), as well as woody stems of bamboo and yucca carbonized at 400 °C. The content of porous carbon in a blend does not exceed 20 wt%. Thermogravimetric analysis (TGA) and dynamic mechanical analysis (DMA) are used in the study. The weight loss during low-temperature pyrolysis (<600 °C), and storage/loss elastic moduli measured as a function of the increasing temperature are related to the kind and concentration of additives. The temperature dependences of elastic moduli determined for binary coal blends differ clearly from those of ternary coal blends. The consumption of energy during the interaction of the components in binary blends was found to be distinctly bigger than the one observed for ternary blends. Non-softening additives such as carbonized plants and low rank coal, containing many functional groups, diminish both moduli of the blends distinctly. However, the addition of coke does not reduce the value of the elastic moduli but increases the width of the maximum occurring in the temperature dependence of the moduli. The influence of the coke

additive on rheological properties of the blends, different in comparison with the remaining additives studied, was assigned with different number of functional groups and radicals.

11/00992 The effect of CO_2 saturation on mechanical properties of Australian black coal using acoustic emission

Ranjith, P. G. *et al. Fuel*, 2010, 89, (8), 2110–2117.

Acoustic emission (AE) methods are now widely used for damage evaluation. For a better understanding of the damage mechanics of materials such as rocks, AE has been used to monitor stresses which induce crack closure, crack initiation and crack damage. In the present study, an AE system was used to study the damage behaviour of some Australian black coal samples subjected to uniaxial compression. Several samples were left in a container filled with 100% CO_2 at a certain pressure for 72 h prior to testing. The results were compared with samples which had only been exposed to the atmosphere to see if CO_2 had any adverse effect on the strength of coal. Strain gauges were installed on the samples and the measured axial and volumetric strains were studied in conjunction with the AE counts. The AE method was successfully used for detecting the onset of crack initiation and the crack damage stress threshold of the black coal samples. Of the coal samples examined, crack initiation and crack closure of the samples subjected to saturation with CO_2 occurred at stress corresponding to a higher percentage of the peak strength when compared to the samples which had only been exposed to atmospheric conditions. However, crack damage occurred at a higher percentage of peak strength and the average peak strength showed a higher value for samples in atmospheric condition when compared to CO_2 saturated samples. The results show that sorption of CO_2 can cause a reduction in strength of the black coal samples when tested under uniaxial compression. As the coal samples were highly inhomogeneous more tests are required in order to be able to confirm whether the adsorption of CO_2 will cause strength reduction in coal and to identify the actual underlying mechanisms.

11/00993 The petrographical and organic geochemical composition of coal from the East field, Bogovina Basin (Serbia)

Životić, D. *et al. International Journal of Coal Geology*, 2010, 81, (4), 227–241.

A petrological and organic geochemical study was performed on coal samples from the East field deposit, Bogovina Basin, Serbia. Fourteen coal samples were collected from different parts of the main and upper coal seams from fresh, working faces in the underground subbituminous coal mine. The Lower Miocene coal of the East field is a typical humic coal with huminite, liptinite and inertinite concentrations of up to 81.4, 16.1 and 13.5 vol.%, respectively. Densinite is the most abundant maceral with variable amounts of ulminite and gelinite. Sporinite and liptodetrinite are the most common macerals of the liptinite group. Exsudatinite was detected in the lower part of the Lower coal seam. Inertodetrinite is the most abundant maceral of the inertinite group. The mineral matter consists mostly of clay minerals and carbonates. The mean random huminite reflectance (ulminite B) for the Main coal seam is 0.42 ± 0.04%Rr, and 0.41 ± 0.04%Rr for the Upper coal seam, which are typical for an immature to early mature stage of the organic matter. The distribution and abundance of *n*-alkanes and steranes indicates a significant contribution of epicuticular waxes from higher plants. High amount of phyllocladane-type diterpenoids (16α(H)-phyllocladane) suggests that coal-forming plants were conifer families Taxodiaceae, Podocarpaceae, Cupressaceae, Araucariaceae, Sciadopityaceae, and Phyllocladaceae, while a higher amount of pimarane and norpimarane suggests Pinaceae, Taxodiaceae, and Cupressaceae. The pristane/phytane (Pr/Ph) ratio implies variable anaerobic to oxic conditions during sedimentation. The distribution of the hopanes detected in the Bogovina East field coal indicates an immature to early mature stage of the organic matter, which is in agreement with huminite reflectance. The high coal sulfur contents from the East field are characteristic for slightly alkaline depositional environments generated by bentonite from the basement of the Main coal seam. The petrological observation and biomarker composition provide evidence for the generation of immature hydrocarbons which, most probably, originated from the resins and waxes of higher plants, mostly gymnosperms.

Preparation

11/00994 CFD modeling of MPS coal mill with moisture evaporation

Bhambare, K. S. *et al. Fuel Processing Technology*, 2010, 91, (5), 566–571.

Coal pulverizers play an important role in the functioning and performance of a PC-fired boiler. The main functions of a pulverizer are crushing, drying and separating the fine coal particles toward combustion in the furnace. It is a common experience that mill outlet pipes have unequal coal flow in each pipe and contain some coarse particles. Unequal coal flow translates into unequal air-to-fuel ratio in the burner, deviating from the design value and thus increasing unburned carbon in fly ash, NO_x and CO. Coarser particles at the mill outlet originate from poor separation and decrease the unit efficiency. In addition, coarser particles reduce burner stability at low load. Air flow distribution at the mill throat, as well as inside the mill, significantly influences the mill performance in terms of separation, drying, coal/air flow uniformity at the mill outlet, wear patterns and mill safety. In the present work, a three-dimensional computational fluid dynamics (CFD) model of the MPS Roll Wheel pulverizer at Alliant Energy's Edgewater Unit 5 has been developed. The Eulerian–Lagrangian simulation approach in conjunction with the coal drying model in Fluent, a commercial CFD software package, has been used to conduct the simulation. Coal drying not only changes the primary air temperature but it also increases the primary air flow rate due to mass transfer from coal. Results of the simulation showed that a non-uniform airflow distribution near the throat contributes significantly to non-uniform air–coal flow at the outlet. It was shown that uniform velocity at the throat improves the air and coal flow distribution at the outlet pipes. A newly developed coal mill model provides a valuable tool that can be used to improve the pulverizer design and optimize unit operation. For example, reject coal rate, which is controlled by the air flow near the mill throat, can be reduced. The model can also be used to further aid in identifying and reducing high temperature or coal-rich areas where mill fires are most likely to start.

11/00995 Coal lump devolatilization and the resulting char structure and properties

Minkina, M. *et al. Fuel Processing Technology*, 2010, 91, (5), 476–485.

Lumps of six bituminous coals, from 20 to 40 mm in size, were devolatilized in a laboratory oven in nitrogen atmosphere at different final temperatures ranging from 300 to 800 °C. The structure and morphology of the resulting chars with different degree of devolatilization have been examined under an optical microscope in order to better understand the formation mechanism of different types of char. The swelling of the caking coals and the fissuring of the non-caking coals were characterized by image analysis and some correspondences between the distribution of lithotypes within the initial coal lumps and the char structure obtained were revealed. The relation between chars structure and properties was also investigated. The char lumps obtained from caking coal exhibit better resistance to breakage than their parent coal lumps while non-caking coals show the opposite behaviour. For both caking and non-caking coals, a significant decrease of resistance is observed in the intensive devolatilization temperature range from 400 to 600 °C.

11/00996 Energy-efficient coal dewatering using liquefied dimethyl ether

Kanda, H. and Makino, H. *Fuel*, 2010, 89, (8), 2104–2109.

In this study, the authors dewatered sub-bituminous coal mined in Warra, Indonesia, by using liquefied dimethyl ether (DME); no heating was required in this dewatering process. This dewatering was achieved both in a laboratory-scale experiment and using a previously developed bench-scale equipment. The properties of the coal before and after dewatering were also examined and the amount of energy required by the equipment was measured. It was found that the maximum water extraction efficiency of liquefied DME was 98.3%. Further, the properties of the coal did not change after the dewatering treatment. The wastewater obtained by dewatering can be treated by existing wastewater treatment technologies. The energy consumed by the bench-scale equipment was 2069 kJ/kg-water; thus, this dewatering process using liquefied DME was confirmed to be effective and energy efficient.

11/00997 Kinetic modeling of liquid generation from oil shale in fixed bed retort

Al-Ayed, O. S. *et al. Applied Energy*, 2010, 87, (7), 2273–2277.

Kinetics of shale oil generation in a fixed bed retort is modelled using a second-order rate equation. Samples from Ellajjun oil shale deposits are tested in 350–550 °C temperatures range. In each run, 400 g are charged to reactor and heated in a range of 2.2–10 °C min^{-1}. Shale oil liquid is condensed at 0 ± 2 °C and its rate measured as function of time and temperature. Increasing heating rate from 2.2 to 10 °C min^{-1} decreased activation energy from 115 to 71.2 kJ mol^{-1} and frequency factor from 2.85×10^7 to 9.0×10^3 correspondingly. The generated data are modelled using Coats and Redfern differential and integral models. Good agreement has been obtained.

Economics, business, marketing, policy

11/00998 Clean coal technology development in China

Chen, W. and Xu, R. *Energy Policy*, 2010, 38, (5), 2123–2130.

Coal is found in huge amounts throughout the world and is expected to play a crucial role as an abundant energy source. However, one critical issue in promoting coal utilization is controlling environmental pollution. Clean coal technologies are needed to utilize coal in an environmentally acceptable way and to improve coal utilization efficiency. This paper describes coal's role in China's energy system and the environmental issues related to coal use. Coal is responsible for 90% of the SO_2 emissions, 70% of the dust emissions, 67% of the NO_x emissions, and 70% of the CO_2 emissions. But as the most abundant energy resource, it will continue to be the dominant energy supply for a long time. Therefore, the development and deployment of clean coal technologies are crucial to promote sustainable development in China. Clean coal technologies currently being developed in China are described including high efficiency combustion and advanced power generation technologies, coal transformation technologies, IGCC (integrated gasification combined cycle) and carbon capture and storage (CCS). Although China only recently began developing clean coal technologies, there have been many successes. Most recent orders of coal-fired power plants are units larger than 600 MW and new orders for supercritical and ultra supercritical systems are increasing rapidly. Many national research programs, industrial research programs and international collaboration projects have been launched to develop on IGCC and CCS systems in China. Finally, suggestions are given on how to further promote clean coal technologies in China.

11/00999 Growing Chinese coal use: dramatic resource and environmental implications

Shealy, M. and Dorian, J. P. *Energy Policy*, 2010, 38, (5), 2116–2122.

Chinese coal consumption continues to rise as the country's economy and industry expand. Coal is particularly critical for China's fast-growing power sector, generating about 80% of electricity output. Notwithstanding the importance of coal and electricity, many international forecasts today underestimate their rising use in China. This paper acknowledges the current world financial crisis and assumes that Chinese GDP growth to 2025 will not again approach double-digit levels. Using the scenario analysis, this paper demonstrates that even with conservative assumptions about Chinese GDP growth and income elasticity of electric demand to 2025, the country will likely experience much higher coal demand and emit much greater volumes of carbon dioxide than forecast by various international energy agencies. The paper also analyses how China's domestic coal reserves may be threatened within two decades, possibly affecting long-term economic growth in China, as well as world coal prices.

11/01000 The causal dynamics between coal consumption and growth: evidence from emerging market economies

Apergis, N. and Payne, J. E. *Applied Energy*, 2010, 87, (6), 1972–1977.

This study examines the relationship between coal consumption and economic growth for 15 emerging market economies within a multivariate panel framework over the period 1980–2006. The heterogeneous panel cointegration results indicate there is a long-run equilibrium relationship between real GDP, coal consumption, real gross fixed capital formation, and the labour force. While in the long-run both real gross fixed capital formation and the labour force have a significant positive impact on real GDP, coal consumption has a significant negative impact. The panel causality tests show bidirectional causality between coal consumption and economic growth in both the short and long run.

11/01001 Use of lower grade coals in IGCC plants with carbon capture for the co-production of hydrogen and electricity

Cormos, C.-C. *et al. International Journal of Hydrogen Energy*, 2010, 35, (2), 556–567.

This paper investigates the potential use of lower grade coals in an IGCC-CCS plant that generates electricity and produces hydrogen simultaneously with carbon dioxide capture and storage. The paper underlines one of the main advantages of gasification technology, namely the possibility to process lower grade coals, which are more widely available than the high-grade coals normally used in European power plants. Based on a proposed plant concept that generates about 400 MW net electricity with a flexible output of 0–50 MW_{th} hydrogen and a carbon capture rate of at least 90%, the paper develops fuel selection criteria for coal fluxing and blending of various types of coal for optimizing plant performance, e.g. oxygen consumption, hydrogen production potential, specific syngas energy production per tonne of oxygen consumed, etc. These performance indicators were calculated for a number of case studies through process flow simulations. The main conclusion is that blending of coal types of higher and lower grade is more beneficial in terms of operation and cost performance than fluxing high-grade coals.

Derived solid fuels

11/01002 Applicability of biogas digestate as solid fuel

Kratzeisen, M. *et al. Fuel*, 2010, 89, (9), 2544–2548.

Biogas digestate is a byproduct in biogas plants. Using the dried digestate as solid fuel seems to be a promising alternative. Objectives were to verify whether digestate from biogas plants is suitable as a solid biomass fuel and to classify the digestate according to current regulations for biofuels. Combustion experiments in a biomass combustion facility were carried out to ascertain both, emissions and combustion behaviour. Two different digestates were used as test fuel and pressed into pellets. Net calorific value of digestate pellets were between 15.8 and 15.0 MJ/kg with water content of 9.2% and 9.9%. Ash content was between 14.6% and 18.3%, with softening temperature between 1090 and 1110 °C. Major compounds of ash were calcium 13.6–17.0%, phosphorous 20.4–26.7%, silicon 18.0–30.4% and potassium with 8.5–15.5%. The average concentration of carbon monoxide was between 104 and 275 mg/m^3 and 334–398 mg/m^3 of nitrogen oxides. Average dust concentration of 100–106 mg/m^3 has been detected, which was reduced to 40–43 mg/m^3 by using an electric filter. Chemical composition and physical properties of digestate fuel pellets depend on the blend of substrates used as feedstock for biogas production. The digestates investigated in this study can be recommended as a fuel for combustion. The calorific value, the ash properties and the emissions allow their use in the investigated solid biomass combustion unit. Further investigations are required to cover a broader range of digestates and combustion techniques.

11/01003 Changes in a coke structure due to reaction with carbon dioxide

Pusz, S. *et al. International Journal of Coal Geology*, 2010, 81, (4), 287–292.

Technological properties of a coke directly depend on a coke structure, i.e. on carbon matrix (a solid phase in a porous medium) and on pore system. Coke structure is deeply transformed during blast furnace operation and one of the most important factors responsible for that is the CO_2 gasification. The objective of this work was to investigate changes of the physical structure of a coke upon the reaction with carbon dioxide to evaluate the effects of structural transformations on technological properties of a coke. Selected physical parameters of cokes produced in a laboratory scale were carried out prior to and after the reaction with CO_2. The following physical methods were used for the study: helium gas densitometry, physical adsorption of N_2, optical microscopy, transmission electron microscopy, ultrasonic measurements and electron paramagnetic resonance spectroscopy. The results showed that the reaction with CO_2 distinctly affects the physical structure of coke. Coke solid matrix becomes better ordered, with greater structural units, while development of pore structure consists in the enlargement and coalescence of pores and the increase of specific surface area. Great increase of coke porosity after the reaction with CO_2 seems to be more affecting the final strength and reactivity of coke than the transformation of carbon matrix.

11/01004 Coke deposition mechanism on the pores of a commercial Pt–Re/γ-Al_2O_3 naphtha reforming catalyst

Baghalha, M. *et al. Fuel Processing Technology*, 2010, 91, (7), 714–722.

Coke deposition mechanism on a commercial Pt–Re/γ-Al_2O_3 naphtha reforming catalyst was studied. A used catalyst that was in industrial reforming operation for 28 months, as well as the fresh catalyst of the unit were characterized using XRD, XRF, and nitrogen adsorption/desorption analyses. Carbon and sulfur contents of the fresh and the used catalysts were determined using Leco combustion analyser. The pore size distributions (PSD) of the fresh and the used reforming catalysts were determined using BJH and comparison plot methods. The comparison plot method produced the most reasonable PSDs for the catalysts. Through comparison of the PSDs of the fresh and the used catalysts, it was revealed that coke deposited on both micropores and mesopores of the catalyst at a constant thickness of 1.0 nm. The constant coke thickness on the catalyst pore walls in the naphtha reforming process (temp. ~500 °C) implies that coke deposition reaction is the slow controlling step in comparison to the fast mass transfer rate of coke ingredients into the pores. The bulk density of the deposited coke on the used catalyst was calculated as 0.966 g/cm^3.

11/01005 Mild coal extraction for the production of anode coke from Blue Gem coal

Andrews, R. J. *et al*. *Fuel*, 2010, 89, (9), 2640–2647.

The quality and availability of petroleum coke used in the manufacture of carbon anodes for aluminium production is a growing concern to the industry. Coke quality and yields have progressively declined as changes in refinery practice and the move towards processing an increasing proportion of heavier sour crudes have affected coke properties, resulting in an increase in the metal impurities and sulfur content of the coke. An alternative supply of anode coke is required to supplement or eventually replace calcined petroleum coke. The significant domestic reserves of coal could represent a viable carbon resource for anode production, provided defined coke specifications can be met and at a cost that is economically viable. The principal objective of this study was to examine the feasibility of producing anode grade coke by the UKCAER process for the mild solvent extraction of coal. Blue Gem coal from eastern Kentucky was dissolved in a high boiling point solvent, the mineral matter and unreacted products removed by filtration, and the clean coal liquid converted to coke. The performance of the coal in solvent extraction was compared to a very reactive coal from western Kentucky. A simple solvent-extraction screening test was established to assess potential candidate materials and process variables without the need for prolonged and complex routines. The coals were assessed in more detail to determine the optimum process conditions by conducting larger scale extraction tests to yield sufficient material for conversion to coke. The green cokes were calcined and the products characterized. The composition and structure of the calcined cokes were compared to typical petroleum coke and assessed for their use in the fabrication of carbon anodes.

11/01006 Noncovalent functionalization of carbon nanotubes with maleimide polymers applicable to high-melting polymer-based composites

Morishita, T. *et al*. *Carbon*, 2010, 48, (8), 2308–2316.

As novel carbon nanotube (CNT) dispersants are effective not only for obtaining stable CNT-dispersed solutions but also for high-melting polymer/CNT composites, the authors synthesized maleimide polymers (MIPs) using *N*-substituted maleimide for imparting physical adsorption on the CNT surfaces and high heat resistance. The MIPs showed strong physical adsorption on various CNT surfaces and good solubility in a wide variety of organic solvents, and acted as excellent CNT dispersants in these substances. The MIPs on the CNT surfaces were very stable at high temperatures (approximately $\geq$300 °C) required for melt mixing using high-melting polymers. The addition of MIP-adsorbed CNTs (CNT/MIPs) to poly(1,4-phenylene sulfide) (PPS) as a high-melting polymer was, therefore, effective for dispersing CNTs and improving the physical properties of the resulting PPS/CNT/MIP composites, in comparison with the PPS/CNT composites. Even at a low CNT loading (1 vol%), the storage modulus of the PPS/CNT/MIP composites increased drastically. Furthermore, thermal conductivity of the PPS/CNT/MIP composites also improved, in comparison with the PPS/CNT composites. These results are considered to be due to an increase of interactions between the CNT and PPS matrices, caused by the stable formation of MIPs on the CNT surfaces.

11/01007 Optimization of experimental conditions for recovery of coking coal fines by oil agglomeration technique

Chary, G. H. V. C. and Dastidar, M. G. *Fuel*, 2010, 89, (9), 2317–2322.

The significance of coking coal in the metallurgical sector as well as the meagre coking coal reserves across the globe increase the necessity to recover coking coal fines from the fine coking coal slurries generated from coal preparation and utilization activities. Oil agglomeration studies were carried out by varying the experimental conditions for maximum recovery of coking coal fines, i.e. yield of the agglomerates. The various operational parameters studied were oil dosage, agitation speed, agglomeration time and pulp density. By using Taguchi experimental design, oil dosage (20%), agitation speed (1100 rpm), agglomeration time (3 min) and pulp density (4.5%) were identified as the optimized conditions. A confirmation experiment has also been carried out at the optimized conditions. The percentage contribution of each parameter on agglomerate yield was analysed by adopting analysis of variance (ANOVA) statistical method as well as multiple linear regression analysis. The order of influence of the parameters on the agglomerate yield is of the following order: pulp density > oil dosage > agitation speed > agglomeration time. A mathematical model was developed to fit the set of experimental conditions with the yield obtained at each test run and also at the optimized conditions. The experimentally obtained yield was compared with the predicted yield of the model and the results indicate a maximum error of 5% between the two. A maximum yield of 90.42% predicted at the optimized conditions appeared to be in close agreement with the experimental yield thus indicating the accuracy of the model in predicting the results.

02 LIQUID FUELS

Sources, properties, recovery

11/01008 Application of HIGEE process intensification technology in synthesis of petroleum sulfonate surfactant

Zhang, D. *et al*. *Chemical Engineering and Processing: Process Intensification*, 2010, 49, (5), 508–513.

Petroleum sulfonate surfactant used for enhanced oil recovery was synthesized by dilute liquid sulfur trioxide and petroleum fraction of Shengli crude oil as raw materials with the application of HIGEE process intensification technology. The effects of various experimental conditions on the content of active matter and unsulfonated oil were investigated. The optimum conditions were selected as solvent/oil mass ratio 0.5, SO_3/oil mass ratio 0.525, reaction temperature 30 °C, rotating speed 1200 rpm, circulation ratio 4, reaction time 15 min and aging time 50 min under which the active matter content was up to 45.3 wt% and the oil/water interfacial tension was as low as 4.5×10^{-3} mN/m. The higher product quality and higher process efficiency of this new technology is proven by a comparison with traditional STR process.

11/01009 Geochemical characterization of solid residues, bitumen and expelled oil based on steam pyrolysis experiments from Irati oil shale, Brazil: a preliminary study

Franco, N. *et al*. *Fuel*, 2010, 89, (8), 1863–1871.

Steam pyrolysis experiments were performed on immature samples from the Irati oil shale, Paraná Basin, Brazil, using a maximum temperature of 350 °C with up to 98 h exposure time at that temperature. The objectives were to study geochemical and petrographical changes in the source material during stepwise increase in maturity, in steam conditions, comparing the properties of expelled oil with the bitumen retained in the solid residue after experimentation. Petrographical and geochemical parameters such as vitrinite reflectance and T_{max}, indicated an increase in maturity related to the exposure time of the organic matter to the maximum temperature. However, biomarker ratios such as 22S/(22S + 22R) C_{31} and C_{32} homohopanes, 20S/(20S + 20R) and $\alpha\beta\beta/(\alpha\beta\beta + \alpha\alpha\alpha)$ C_{29} sterane, which are considered to be indicators of organic matter maturity levels, did not reach their equilibrium values. Some biomarkers frequently used as indicators of specific sources and/or paleoenvironments of deposition such as hopane/sterane ratio, and the concentrations of C_{27} and C_{29} steranes showed significant variations related to the stage of maturity. Based on the evaluation of Rock-Eval parameters, the transformation ratios in steam pyrolysis conditions reached levels higher than 80% in samples having 9 and more hours of exposure time to maximum temperature. Bitumen was found to be enriched in components of heavier molecular weight (resins and asphaltenes), whereas the expelled oils contained higher quantities of aliphatic and aromatic components. At relatively low maturity levels the *n*-alkane distribution of expelled oils indicate a somewhat higher maturity level when compared to the *n*-alkane distribution of the bitumen retained in the source rock, whereas at higher maturity levels the *n*-alkane distribution for the expelled oil and for the bitumen is very similar.

11/01010 Improved hydrocarbons analysis of heavy petroleum fractions by high temperature comprehensive two-dimensional gas chromatography

Dutriez, T. *et al*. *Fuel*, 2010, 89, (9), 2338–2345.

Conventional comprehensive two-dimensional gas chromatography (2D-GC or GC × GC) is now widely used for middle distillates analysis; only a few applications are devoted to heavy fractions such as vacuum gas oils or vacuum residues. A recent extension of GC × GC range in suitable high temperature conditions allowed quantitative analysis of a full vacuum gas oil (VGO) up to nC_{60}. Considering this study as a new breakthrough for the challenge of heavy petroleum fractions analysis, the application of high-temperature two-dimensional gas chromatography (HT-2D-GC) to 12 VGOs from different origins (geographic and processes) and one de-asphalted oil (DAO) is described in this paper. The comparison with standardized methods, liquid chromatography and mass spectrometry, illustrates the reliability of the method for heavy cuts analysis. Furthermore, quantitative distributions by chemical families could be built for the first time, which allow a better description and more relevant comparisons between heavy petroleum fractions. Except for heavier cuts such as DAO, this powerful technique is widely applicable on VGO fractions. These results should increase the analytical information concerning heavy cuts and will be helpful to understand reactions involved in petroleum processes.

11/01011 Organic petrology of subbituminous carbonaceous shale samples from Chalaw, Kabul Province, Afghanistan: considerations for paleoenvironment and energy resource potential

Hackley, P. C. *et al. International Journal of Coal Geology*, 2010, 81, (4), 269–280.

Neogene subbituminous carbonaceous shale deposits from Chalaw, Afghanistan, were investigated through organic petrology techniques and standard coal analyses to determine paleoenvironment and potential for resource utilization. The Chalaw deposit, approximately 30 km south-east of Kabul, currently is exploited for brick making and domestic heating and cooking. Three multiple-bench channel samples of the mined bed at Chalaw were collected and evaluated. The presence of significant huminite (ranging from 0.2 to 59.0 vol.%, mineral-inclusive basis) is suggestive of a terrestrial lignin-rich precursor plant material. Measured reflectance values of 0.38–0.55% indicate subbituminous rank. This rank suggests burial depths of approximately 1500 m and maximum temperatures of approximately 50 °C. Structured liptinite macerals generally are absent except for some fluorescing morphologies interpreted to be poorly-preserved root cork suberinite. Sponge spicule bioliths including gemmoscleres and megascleres are common. These petrographic observations, in addition to high mineral matter content (33 to > 95 vol.%), medium to high sulfur content (2.1–11.5 wt%, dry basis; db), and the presence of common gastropod shell fragments and an aragonite-needle chalk bed are consistent with, but not directly indicative of, a marginal marine or estuarine mangrove depositional environment. However, additional data are necessary to confirm this hypothesis and deposition in a freshwater environment cannot be ruled out at this time. Commercial-scale development and utilization of the Chalaw deposit as a thermal fuel resource may be possible using a fluidized bed combustion system which could accept the low-quality mine product currently produced. Samples examined herein contain high-ash yield (45–90 wt%, db), high total moisture content (17–39 wt%), low calorific value (980–6860 Btu/lb, m,mmf), and have poor agglomerating properties (FSI = 0), consistent with fuels utilized in fluidized bed combustors. However, delineation of the extent of the deposit through field investigation will be necessary to make a quantified resource estimate for mine planning.

11/01012 The Buçaco Basin (Portugal): organic petrology and geochemistry study

Flores, D. *et al. International Journal of Coal Geology*, 2010, 81, (4), 281–286.

The Buçaco Basin includes a Carboniferous/Permian sequence that comprises, from bottom to top, the following stratigraphic sequence: Algeriz Formation, Vale da Mó Formation and Monsarros Formation. Algeriz Formation is constituted by deposits of basal breccia with variable thickness and alternating layers of siltstone, mudstone and conglomerate. Vale da Mó Formation corresponds to lacustrine deposits comprising massive red beds in the base, that pass alternatively to silty-mudstones, shales and grey mudstones with organic matter; this formation also includes a thin coal seam. Monsarros Formation includes fluvial conglomeratic deposits prevalent in the base and top, separated by layers of siltstone and mudstone, redder to the top. The Buçaco Basin opens as a pull-apart basin, into the Porto-Coimbra-Tomar shear zone and later is affected by the clockwise (dextral) movement of this N10°W shear zone. The petrographic study of samples from Vale da Mó Formation showed that the organic matter corresponds to a type III kerogen, derived from higher land plants (gas-prone). The thermal maturation level of the strata was determined using random vitrinite reflectance, with values ranging from 0.72% to 0.80% (%Rr). Rock-Eval pyrolysis showed that Vale da Mó Formation is the only one with potential to generate hydrocarbons, an observation consistent with the petrographic characteristics. TOC ranges from 0.08% to 1.52%. Monsarros Formation reported the highest values for S1/TOC index.

Transport, refining, quality, storage

11/01013 Biodesulfurization of dibenzothiophene, its alkylated derivatives and crude oil by a newly isolated strain *Pantoea agglomerans* D23W3

Bhatia, S. and Sharma, D. K. *Biochemical Engineering Journal*, 2010, 50, (3), 104–109.

Biocatalytic desulfurization (BDS) of fuels has been shown to be a potential alternative to the conventional hydrodesulfurization (HDS) process used in refineries, since HDS cannot remove the heterocyclic organo-sulfur compounds such as dibenzothiophene (DBT). Herein the isolation of a DBT desulfurizing mesophilic bacterium, characterized as *Pantoea agglomerans* D23W3, from contaminated soils collected from refinery has been reported. HPLC analysis revealed that *P. agglomerans* D23W3 could convert DBT to 2-hydroxybiphenyl (2-HBP) via the 4S pathway and that it could degrade 93% of the 100 ppm DBT within 24 h of culture. In addition *P. agglomerans* D23W3 could also desulfurize 4,6-dimethyl DBT and benzothiophene which are among the most difficult DBT derivatives to be removed by HDS. Further, adapted cells of *P. agglomerans* D23W3 were found to remove 26.38–71.42% of sulfur from different petroleum oils with highest sulfur removal from light crude oil. Therefore, *P. agglomerans* D23W3 has a potential for the BDS of the petroleum oils.

11/01014 Differences between ZSM-5 and ZSM-11 zeolite catalysts in 1-hexene aromatization and isomerization

Zhang, L. *et al. Fuel Processing Technology*, 2010, 91, (5), 449–455.

ZSM-5 and ZSM-11 zeolites with high crystallinity are synthesized and tested in the aromatization and isomerization reactions of 1-hexene at 370 °C in a continuous flow fixed bed. The results indicate that ZSM-5 and ZSM-11 zeolites possess similar acid site amount and strength, and most of the acid sites belong to Brønsted acid. When the ZSM-5 and ZSM-11 zeolites were used as catalysts, the aromatics selectivity over ZSM-11 catalyst was higher than that over ZSM-5 catalyst in contrast to *i*-paraffins selectivity, maybe attributed to that the C_7 and C_8 aromatics have an easier exit from the ZSM-11 zeolite. Moreover, the decrease of particle size can present superior aromatics selectivity and less *i*-paraffins selectivity in the aromatization and isomerization of 1-hexene over the ZSM-11 catalyst.

11/01015 Infinite dilution activity coefficient and vapour liquid equilibrium measurements for dimethylsulphide and tetrahydrothiophene with hydrocarbons

Haimi, P. *et al. Fluid Phase Equilibria*, 2010, 295, (1), 17–25.

The activity coefficients at infinite dilution (γ_∞) of dimethylsulfide (DMS) in four hydrocarbon solvents were measured using the dilutor technique at temperatures between 288 K and 303 K. The four hydrocarbons were hexane, 1-hexene, 2,2,4-trimethylpentane and 2,4,4-trimethyl-1-pentene. The dilutor technique is based on the stripping of the highly diluted solute, i.e. DMS, by a constant flow of inert gas. The gas composition was analysed by gas chromatography and the rate of solute removal was calculated from the area of the peaks. In addition, a static total pressure apparatus was used to measure the vapour–liquid equilibrium of the binary systems of propane + DMS and propane + tetrahydrothiophene at 293 K and 313 K. In the static total pressure method, the analysis of the constituent phases is avoided. The systems' components were injected to the equilibrium cell in known amounts. The composition of the liquid and vapour phase was calculated from the measured temperature and total pressure. The parameters for the Wilson activity coefficient model were regressed. When possible, a comparison between the experimental results and data found in the literature was performed.

11/01016 Ionic liquids on desulfurization of fuel oils

Francisco, M. *et al. Fluid Phase Equilibria*, 2010, 294, (1–2), 39–48.

In this paper, a review about the role of Ionic Liquids on desulfurization of fuel oils has been done. From these salts, the pyridiniums are showing the most promising results on sulfur reduction by simple liquid–liquid extraction. For this reason, in this work the suitability of a new pyridinium ionic liquid as solvent in the extraction of sulfur- and nitrogen-containing compounds from fuels has been analysed. Liquid + liquid equilibrium data for 1-hexyl-3,5-dimethyl pyridinium {bis[trifluoromethylsulfonyl]imide} + thiophene + *n*-hexane or *n*-dodecane or *n*-hexadecane and 1-hexyl-3,5-dimethyl pyridinium {bis[trifluoromethylsulfonyl]imide} + pyridine + hexane ternary systems have been determined at 298.15 K and atmospheric pressure. High solubility of thiophene and pyridine in ionic liquid but also of toluene, has been found, being this salt practically inmiscible with linear hydrocarbons. Equilibrium data of these systems have been correlated with UNIQUAC and NRTL models driving to high deviations at high solute concentrations. Three steps extraction experiments with simulated gasoline and diesel and also with real samples, previous to refinery desulfurization process, confirmed ability of ionic liquid [hmmpy][Ntf_2] as solvent for extractive desulfurization of transportation fuels.

11/01017 Methods for the determination of conjugated dienes in petroleum products: a review

de Andrade, D. F. *et al. Fuel*, 2010, 89, (8), 1796–1805.

The present review surveys the existing methods of analysis for the determination of conjugated dienes in petroleum products, including both chemical and instrumental techniques. Several methods of quantifying the total conjugated dienes amount in complex hydrocarbon mixtures have already been reported. However, the identification of each conjugated diene has been proved to be a difficult task

to be done although a detailed analysis will enable a good correlation with the gum formation and the catalyst poisoning. Here the scope and limitation of each method in relation of its applicability to specific petroleum products are fully discussed.

11/01018 The rivulet flow pattern during oil–water horizontal flow through a 12 mm pipe

De, B. *et al. Experimental Thermal and Fluid Science*, 2010, 34, (5), 625–632.

The present study reports the hydrodynamics of the rivulet pattern during oil–water flow through a 12 mm horizontal acrylic pipe. The interfacial distribution has been observed visually and characterized from signals obtained from an optical probe as well as by isokinetic sampling. The probability density function and fast Fourier transform of the signals have provided an understanding of the flow configuration. The experiments have revealed that although rivulet flow is a typical separated flow pattern, it has different characteristics as compared to the stratified and annular flow patterns. The holdup and pressure drop under such conditions have been compared with the drift flux model for horizontal flow as well as the two-fluid model as proposed by Brauner and Maron for liquid–liquid flows.

Economics, business, marketing, policy

11/01019 Assessment of CO_2 emissions and its reduction potential in the Korean petroleum refining industry using energy-environment models

Park, S. *et al. Energy*, 2010, 35, (6), 2419–2429.

The authors assessed potential future CO_2 reduction in the Korean petroleum refining industry by investigating five new technologies for energy savings and CO_2 mitigation using a hybrid SD-LEAP model: crude oil distillation units (CDU), vacuum distillation units (VDU), light gas-oil hydro-desulfurization units (LGO HDS), and the vacuum residue hydro-desulfurization (VR HDS) process. The current and future demand for refining industry products in Korea was estimated using the SD model. The required crude oil input amounts are expected to increase from 139 million tons in 2008 to 154 million tons in 2030 in the baseline scenario. The current and future productivity of the petroleum refining industry was predicted, and this prediction was substituted into the LEAP model which analysed energy consumption and CO_2 emissions from the refining processes in the BAU scenario. It is expected that new technology and alternative scenarios will reduce CO_2 emissions by 0.048% and 0.065% in the national and industrial sectors, respectively.

11/01020 Combined production of hydrogen and power from heavy oil gasification: pinch analysis, thermodynamic and economic evaluations

Domenichini, R. *et al. Energy*, 2010, 35, (5), 2184–2193.

The integrated gasification combined cycle (IGCC) represents a commercially proven technology available for the combined production of hydrogen and electricity power from coal and heavy residue oils. When associated with CO_2 capture and sequestration facilities, the IGCC plant gives an answer to the search for a clean and environmentally compatible use of high sulfur and heavy metal contents fuels, the possibility of installing large size plants for competitive electric power and hydrogen production, and a low cost of CO_2 avoidance. The paper describes two new and realistic configurations of IGCC plant fed by refinery heavy residues and including a CO_2 capture section, which are proposed on the basis of the experience gained in the construction of similar plants. They are based on oxygen blown entrained bed gasification and sized to produce a large amount of hydrogen and to feed one or two gas turbines of the combined cycle unit. The main thermodynamic and technological characteristics of the total plants are evaluated focusing on the heat integration between syngas cooling and combined cycle sections. Moreover, the overall performance characteristics and investment cost are estimated to supply a reliable estimate for the cost of electricity, given a value for the hydrogen selling price.

11/01021 Diesel NO_x aftertreatment catalytic technologies: analogies in LNT and SCR catalytic chemistry

Forzatti, P. *et al. Catalysis Today*, 2010, 151, (3–4), 202–211.

This paper reviews the main results of wide investigations dedicated to the understanding of the chemistry and the reaction pathways operating in the reduction of NO_x in LNT and SCR processes for the after-treatment of NO_x in diesel exhausts. In particular, similarities and differences between the two processes will be highlighted. The reactions involved in the NH_3-NO/NO_2-SCR reacting system were investigated by an extensive set of various unsteady-state experiments performed over both vanadium- and zeolite-based commercial catalysts: the bulk of results led to the proposal of an original global mechanistic scheme of the complete NH_3-NO/NO_2-SCR reacting system. In such a scheme, a key role is played by nitrite and nitrate species, which are formed by NO_2 disproportion onto catalyst surfaces. Nitrites are readily reduced by ammonia to dinitrogen, whereas the rate limiting step is the reduction of surface nitrates, performed both by NO at lower temperatures and by NH_3 at higher temperatures possibly via formation of nitrites as intermediates in both cases. The systematic study of LNT processes showed that during the lean phase NO_x is stored onto the catalyst in the form of nitrite and nitrate species. It was also shown that during the subsequent reduction phase NO_x ad-species are reduced to dinitrogen through two consecutive steps in which NH_3 is formed as an intermediate upon reaction of nitrates with H_2, and further reacts with nitrates to selectively produce N_2. Accordingly, in both LNT and SCR chemistries the reduction of NO_x involves nitrite and nitrate surface species which are selectively reduced to nitrogen by ammonia, either formed as an intermediate or supplied as a reactant.

11/01022 Market efficiency of oil spot and futures: a mean-variance and stochastic dominance approach

Lean, H. H. *et al. Energy Economics*, 2010, 32, (5), 979–986.

This paper examines the market efficiency of oil spot and futures prices by using both mean-variance (MV) and stochastic dominance (SD) approaches. Based on the West Texas Intermediate crude oil data for the sample period 1989–2008, no evidence was found of any MV and SD relationships between oil spot and futures indices. This infers that there is no arbitrage opportunity between these two markets, spot and futures do not dominate one another, investors are indifferent to investing spot or futures, and the spot and futures oil markets are efficient and rational. The empirical findings are robust to each subperiod before and after the crises for different crises, and also to portfolio diversification.

11/01023 Petroleum refining industry in China

Walls, W. D. *Energy Policy*, 2010, 38, (5), 2110–2115.

The oil refining industry in China has faced rapid growth in oil imports of increasingly sour grades of crude with which to satisfy growing domestic demand for a slate of lighter and cleaner finished products sold at subsidized prices. At the same time, the world petroleum refining industry has been moving from one that serves primarily local and regional markets to one that serves global markets for finished products, as world refining capacity utilization has increased. Globally, refined product markets are likely to experience continued globalization until refining investments significantly expand capacity in key demand regions. The oil refining industry in China is surveyed in the context of the world market for heterogeneous crude oils and growing world trade in refined petroleum products.

11/01024 Promoting effect of an aluminum emulsion on catalytic performance of Cu-based catalysts for methanol synthesis from syngas

Wang, L. *et al. Fuel Processing Technology*, 2010, 91, (7), 723–728.

Copper-based catalysts modified with aluminium precursors having different morphologies for methanol synthesis were prepared and the effect of the addition of aluminium emulsion on the characteristics of the catalyst was studied by using X-ray diffraction (XRD), temperature-programmed reduction (TPR) and differential thermal gravity (DTG). The experiment results show that the copper-based catalyst prepared by mixing a Cu–Zn precipitate with an amorphous aluminium emulsion prepared in advance by precipitating an aluminium salt with ammonia exhibits higher specific surface area and catalytic performance for methanol synthesis from synthesis gas. The catalysts thus prepared were found to have more $(Cu,Zn)_2CO_3$ $(OH)_2$ phase, from which more Cu/Zn sosoloid was produced during calcination. More sosoloid phase produced and stronger synergy between Cu and ZnO were verified to enhance the activity of the catalyst for methanol synthesis.

11/01025 Simulation, integration, and economic analysis of gas-to-liquid processes

Bao, B. *et al. Fuel Processing Technology*, 2010, 91, (7), 703–713.

Gas-to-liquid (GTL) involves the chemical conversion of natural gas into synthetic crude that can be upgraded and separated into different useful hydrocarbon fractions including liquid transportation fuels. Such technology can also be used to convert other abundant natural resources such as coal and biomass to fuels and value added chemicals [referred to as coal-to-liquid (CTL) and biomass-to-liquid (BTL)]. A leading GTL technology is the Fischer–Tropsch process. The objective of this work is to provide a techno-economic analysis of the GTL process and to identify optimization and integration opportunities for cost saving and reduction of energy usage while accounting for the environmental impact. First, a base-case flowsheet is synthesized to include the key processing steps of the plant. Then, a computer-aided process simulation is carried out to determine the key mass and energy flows, performance criteria, and equipment specifications. Next, energy

and mass integration studies are performed to address the following items: (a) heating and cooling utilities, (b) combined heat and power (process cogeneration), (c) management of process water, (d) optimization of tail gas allocation and (e) recovery of catalyst-supporting hydrocarbon solvents. Finally, these integration studies are conducted and the results are documented in terms of conserving energy and mass resources as well as providing economic impact. Finally, an economic analysis is undertaken to determine the plant capacity needed to achieve the break-even point and to estimate the return on investment for the base-case study.

11/01026 Slow oil shocks and the 'weakening of the oil price–macroeconomy relationship'
Naccache, T. *Energy Policy*, 2010, 38, (5), 2340–2345.
Many papers have documented and analysed the asymmetry and the weakening of the oil price–macroeconomy relationship as of the early 1980s. While there seems to be a consensus about the factors causing the asymmetry, namely adjustment costs which offset the benefits of low energy prices, the debate about the weakening of the relationship is not over yet. Moreover, the alternative oil price specifications which have been proposed to restore the stability of the relationship fail to cause output or unemployment in post-1980 data. By using the concept of accelerations of the oil price, it is shown that the weakening of this relationship corresponds to the appearance of slow oil price increases, which have less impact on the economy. When filtering out these slow oil price variations from the sample, the causality running from the oil price to the macroeconomy is rehabilitated and show that far from weakening, the oil price accelerations–GDP relationship has even been growing stronger since the early 1980s.

Derived liquid fuels

11/01027 A review on coal-to-liquid fuels and its coal consumption
Höök, M. and Aleklett, K. *International Journal of Energy Research*, 2010, 34, (10), 848–864.
As the price of oil continues to rise, so interest in alternative fuels grows. Coal-to-liquids (CTL) is an alternative liquid fuel that has already been commercially and technically established, however there are issues that suggest that for the most part, it can only be a minor contributor and must be combined with other strategies. Conversion ratios for CTL are generally estimated to be between 1 and 2 barrels/ton of coal. This puts a strict limitation on future CTL capacity imposed by future coal production volumes, regardless of other factors such as economics, emissions or environmental concerns. Assuming that 10% of world coal production can be diverted to CTL, the contribution to liquid fuel supply will be limited to only a few mega barrels per day. This prevents CTL from becoming a viable mitigation plan for liquid fuel shortage on a global scale. However, it is still possible for individual nations to derive significant shares of their fuel supply from CTL, but those nations must also have access to equally significant coal production capacities. It is unrealistic to claim that CTL provides a feasible solution to liquid fuels shortages created by peak oil.

11/01028 Coalbed methane liquefaction adopting a nitrogen expansion process with propane pre-cooling
Gao, T. *et al. Applied Energy*, 2010, 87, (7), 2142–2147.
Coalbed methane (CBM) is an important global energy resource and liquefaction is suggested to best utilize it. Different from ordinary natural gas, CBM usually contains a high proportion of nitrogen, which cannot be removed by purification procedures applied in ordinary natural gas liquefaction processes. One approach for separating nitrogen from CBM is by distillation after liquefaction. In this way, nitrogen is liquefied together with methane, and the liquefaction system performance may change along with the nitrogen content of CBM feed gas. The liquefaction process adopting nitrogen expansion with propane pre-cooling is usually considered suitable for small-scale liquefaction plants due to its simplicity and is the focus of this paper. Taking the unit product liquefaction power consumption as the major index for analysis, optimum parameters of the liquefaction process for CBM feed gas containing different nitrogen contents are calculated. Based on the optimization results, the effects of nitrogen content as well as the other two important technical indexes (liquefaction rate and methane recovery rate) on system performance are also investigated.

11/01029 CoZnAl catalysts for ethanol steam reforming reaction
Noelia Barroso, M. *et al. Chemical Engineering Journal*, 2010, 158, (2), 225–232.
The ethanol steam reforming was studied at 500 and 600 °C on CoZnAl catalysts with different Co loading (9 and 25 wt%) and a Zn:Al atomic ratio that was nearly constant (Zn:Al $\approx$ 0.6). The catalysts were prepared by the citrate sol–gel method and characterized by different techniques. They were active in the ethanol steam reforming at atmospheric pressure in the temperature range studied, but with significant differences in their performance. High hydrogen selectivities, better than 80%, were obtained on catalyst with high Co loading (25 wt%). CO, CO_2 and minor amount of CH_4 were the only carbon products at 600 °C.

11/01030 Methanol or ethanol produced from woody biomass: which is more advantageous?
Hasegawa, F. *et al. Bioresource Technology*, 2010, 101, (S1), S109–S111.
In this study, two conversion technologies – methanol synthesis and ethanol fermentation – were compared and CO_2 mitigation effect was estimated. The biomethanol production process was revealed as being preferable to the bioethanol process in terms of thermal efficiency, carbon conversion and environmental burden except electrical energy consumption. When biofuels are employed in internal combustion engines, biomethanol has greater potential for gasoline substitution, but the difference in expected CO_2 reduction is rather small due to higher power consumption in methanol production. Consequently, from a short-term perspective, bioethanol is preferable since it can readily substitute the gasoline for conventional vehicles. From a long-term perspective, however, biomethanol has greater potential for gasoline substitution and CO_2 mitigation.

11/01031 Production of hydrocarbons in Fischer–Tropsch synthesis with Fe-based catalyst: investigations of primary kerosene yield and carbon mass balance
Kumabe, K. *et al. Fuel*, 2010, 89, (8), 2088–2095.
The Fischer–Tropsch synthesis (FTS) of syngas was carried out using Fe-based catalysts in order to produce hydrocarbons (HCs) equivalent to kerosene, which is used as an alternative aviation fuel. The FTS was conducted in a downdraft continuous-flow-type fixed-bed reactor under a temperature of 533–573 K and a pressure of 3.0 MPa. The effects of reduction gases and time of the Fe-based catalyst, reaction temperature and the chemical species included in the Fe-based catalyst on the FTS were studied by focusing on primary kerosene yield and the carbon mass balance. The carbon mass balances in the study were almost 100%. In C6 + HCs, the selectivity of CO to the C11−C14 HCs equivalent to kerosene was found to be the second highest, the highest being its selectivity to C20 + HCs equivalent to wax. The amount of primary kerosene produced was maximum under the following conditions: the prepared Fe catalyst did not contain other chemical species, the feed ratio of the reduction gases H_2:CO:N_2 was 2:1:3, the catalyst reduction time was 8 h, and the FTS reaction temperature was 553 K.

03 GASEOUS FUELS

Sources, properties, recovery, treatment

11/01032 Major ion and isotope geochemistry of fluids and gases from coalbed methane and shallow groundwater wells in Alberta, Canada
Cheung, K. *et al. Applied Geochemistry*, 2010, 25, (9), 1307–1329.
The production of coalbed methane (CBM) represents an important new source of natural gas supply in western Canada. There are, however, concerns over potential negative environmental impacts on shallow groundwater resources in the hypothetical case that leakage of fluids and gases from CBM operations occurs. This paper compares major ion and isotope geochemistry data for produced fluids or gases from two major coal deposits in western Canada (Mannville Formation and the Horseshoe Canyon/Belly River Group) with similar data collected for shallow groundwater in south-central Alberta. The objective was to generate comprehensive baseline geochemical data to determine the key geochemical characteristics and differences of produced fluids and gases from two coal deposits and shallow groundwater in Alberta and to find parameters that are suitable for identifying potential leakage of fluids or gases into shallow groundwater. Shallow groundwater had average total dissolved solids (TDS) of 1037 mg/L. Most samples belonged to the Na–HCO_3–SO_4 water type and average SO_4^{2-} concentrations were 185 mg/L. The Horseshoe Canyon/Belly River Group swabbing fluids had average TDS of 5427 mg/L, a Na–HCO_3 water type, and average SO_4^{2-} concentrations

of 47.7 mg/L. The produced fluids from the Mannville Formation had average TDS contents of 74,500 mg/L, negligible SO_4^{2-} and a Na–Cl water type. Shallow groundwater and produced fluids from the Horseshoe Canyon Formation and the Mannville group had distinct δ^2H and $\delta^{18}O$ values and plotting $\delta^{18}O$ values versus total dissolved solids was found to be an effective approach to distinguish the waters. Sulfur isotope data revealed the occurrence of bacterial (dissimilatory) SO_4 reduction in some shallow groundwater samples and in the produced fluids from the Horseshoe Canyon/Belly River Group. Methane was found in several shallow groundwater samples and its average $\delta^{13}C$ (-72.1 ± 6.8‰) and δ^2H values (-297 ± 17‰) indicated a biogenic origin predominantly from CO_2 reduction. Dissolved gases from the Horseshoe Canyon Formation fluids with average $\delta^{13}C$ values of methane of -54.0 ± 4.1‰ and ethane of -36.5 ± 2.4‰ and traces of higher alkanes suggest a mixture of predominantly biogenic and some thermogenic gas. Dissolved hydrocarbon gas from the Mannville Formation had the highest average $\delta^{13}C$ values of -49.4 ± 3.6‰ for methane, -28.8 ± 2.1‰ for ethane and -26.9 ± 1.1‰ for propane. The presence of higher alkanes suggests that the Mannville produced fluids contain an appreciable thermogenic gas component. The biogenic gas component in the Horseshoe Canyon and the Mannville Formation was mainly formed via acetate fermentation according to α_{CO_2}–CH_4 values between 1.02 and 1.07. It is concluded that $\delta^{18}O$ values of the fluids in concert with total dissolved solids, and the isotopic compositions of methane and ethane are sufficiently distinct in shallow groundwater and produced fluids from the Horseshoe Canyon and the Mannville Formations that they may serve as tracers for evaluating potential contamination of shallow groundwater with produced fluids or gases.

11/01033 NH_3 and HCl impact on sulfur removal from E-Gas™ gasification streams using S Zorb™ Gen. IV

Schmidt, R. and Sughrue, E. L. *Fuel Processing Technology*, 2010, 91, (6), 582–590.

This study is the third in a series examining the extension of the regenerable S Zorb™ SRT (sulfur removal technology) system beyond sulfur removal from gasoline and into its application under warm-gas conditions. Previously, the fourth generation of this sorbent system was found to be effective and regenerable for the removal of up to 1 wt% sulfur from a working gasifier product stream. In this study, the robustness of the system towards exposure to hydrogen chloride and ammonia was tested. The relationship between these compounds and the formation of zinc silicate and zinc sulfate within the sorbent was of particular interest since the formation of these phases most dramatically impacts the absorptive capacity of sulfur.

11/01034 The origin of natural gas and the hydrocarbon charging history of the Yulin gas field in the Ordos Basin, China

Guoyi, H. *et al. International Journal of Coal Geology*, 2010, 81, (4), 381–391.

The genetic type, source and charging history of natural gas in the Yulin gas field in the Ordos Basin have been studied by combining the carbon isotopic composition of natural gas and geochemical characteristics of light hydrocarbons with carbon isotope fractionation model results and fluid inclusion analysis. The carbon isotopic composition of methane and ethane in the Yulin gas field is relatively enriched in ^{13}C with $\delta^{13}C_1$ values ranging from -35.3‰ to -29.8‰ (average value = -32.4‰) and $\delta^{13}C_2$ ranging from -26.3‰ to -23.5‰ (average value = -24.8‰). The C_7 light hydrocarbons are predominated by methylcyclohexane, accounting for 65.8% to 80.9% (average value = 71.6%), which is characteristic of coal-derived gas. Furthermore, the gas geochemistry indicates that, although marine limestone source rocks are present in the region, the contribution of oil-associated gas from this source to the Yulin gas field is quite low. Based on the empirical relationship between $\delta^{13}C_1$ and %Ro of gas source rocks, and the kinetic isotope fractionation predictions for gases generated in the Yulin gas field, the observed $\delta^{13}C$ of methane is heavier than that of natural gas only originated from *in situ* coal-measures. This result shows that gas in the Yulin gas field is contributed not only by the natural gas generated from local coal-measure source rocks, but also from the higher maturity natural gas sourced from the coal-measure source rocks to the south or southwest of this gas field. Fluid inclusion analysis proves that the accumulation of natural gas in the Yulin gas field has the characteristics of continuous charge.

Transport, storage

11/01035 A fatigue initiation parameter for gas pipe steel submitted to hydrogen absorption

Capelle, J. *et al. International Journal of Hydrogen Energy*, 2010, 35, (2), 833–843.

Fatigue initiation resistance has been determined on API 5L X52 gas pipe steel. Tests have been performed on Roman tile specimen and fatigue initiation was detected by acoustic emission. A comparison between specimens electrolytically charged with hydrogen and specimens without hydrogen absorption were made and it has been noted that fatigue initiation time is reduced of about three times when hydrogen embrittlement occurs. It has been proposed to use the concept of notch stress intensity factor as parameter to describe the fatigue initiation process. Due to the fact that hydrogen is localized in area with high hydrostatic pressure, definitions of local effective stress and distance have been modified when hydrogen is absorbed. This modification can be explained by existence of a ductile–brittle transition with hydrogen concentration. The fatigue initiation resistance curve allows that to determine a threshold for large number of cycles of fatigue non-initiation. This parameter introduced in a failure assessment diagram provides supplementary information about defect nocivity in gas pipes: a non-critical defect can be detected as dormant or not dormant defect, i.e. as a non-propagating defect.

11/01036 A MonteCarlo approach for assessing the adequacy of the European gas transmission system under supply crisis conditions

Monforti, F. and Szikszai, A. *Energy Policy*, 2010, 38, (5), 2486–2498.

Europe's dependency on non-EU countries' energy supply is sharply increasing. Recently, sudden supply disruption caused by international disputes outside the EU have created serious problems for some EU countries and raised concern in many others. In these situations, it is highly desirable to have a tool to assess possible outcomes of supply disruptions. This paper presents a newly developed model, MC-GENERCIS, aimed to assess the robustness of the EU transnational gas transmission system during both normal and special operating conditions, including high-demand situations and/or a supply shortage. The model has a country-by-country resolution and examines all possible dispatching choices of national TSOs on the basis of a probabilistic Monte Carlo approach. The preliminary validation of the model through its application to the 'normal' conditions for the winter 2008–2009 and to the recent supply disruption involving Ukrainian gas transit is also described.

11/01037 Cryo-adsorptive hydrogen storage on activated carbon. I: Thermodynamic analysis of adsorption vessels and comparison with liquid and compressed gas hydrogen storage

Paggiaro, R. *et al. International Journal of Hydrogen Energy*, 2010, 35, (2), 638–647.

This paper presents a thermodynamic analysis of cryo-adsorption vessels for hydrogen storage. The analysis is carried out with an unsteady lumped model and gives a global assessment of the behaviour of the storage system during operation (discharge), dormancy and filling. The adsorbent used is superactivated carbon AX-21™. Cryogenic hydrogen storage, either by compression or adsorption, takes advantage of the effect of temperature on the storage density. In order to store 4.1 kg H_2 in 100 L, a pressure of 750 bar at 298 K is necessary, but only 150 bar at 77 K. The pressure is further reduced to 60 bar if the container is filled with pellets of activated carbon. However, adsorption vessels are submitted to intrinsic thermal effects which considerably influence their dynamic behaviour and due to which thermal management is required for smooth operation. In this analysis, among energy balances for filling and discharge processes, the influence of the intrinsic thermal effects during vessel operation is presented. Hydrogen losses during normal operation as well as during long periods of inactivity are also considered. The results are compared to those obtained in low-pressure and high-pressure insulated LH_2 and CH_2 tanks.

11/01038 Geological storage of CO_2 in saline aquifers – a review of the experience from existing storage operations

Michael, K. *et al. International Journal of Greenhouse Gas Control*, 2010, 4, (4), 659–667.

The experience from CO_2 injection at pilot projects (Frio, Ketzin, Nagaoka, US Regional Partnerships) and existing commercial operations (Sleipner, Snøhvit, In Salah, acid-gas injection) demonstrates that CO_2 geological storage in saline aquifers is technologically feasible. Monitoring and verification technologies have been tested and demonstrated to detect and track the CO_2 plume in different subsurface geological environments. By the end of 2008, approximately 20 Mt of CO_2 had been successfully injected into saline aquifers by

existing operations. Currently, the highest injection rate and total storage volume for a single storage operation are approximately 1 Mt CO_2/year and 25 Mt, respectively. If carbon capture and storage (CCS) is to be an effective option for decreasing greenhouse gas emissions, commercial-scale storage operations will require orders of magnitude larger storage capacity than accessed by the existing sites. As a result, new demonstration projects will need to develop and test injection strategies that consider multiple injection wells and the optimization of the usage of storage space. To accelerate large-scale CCS deployment, demonstration projects should be selected that can be readily employed for commercial use; i.e. projects that fully integrate the capture, transport and storage processes at an industrial emissions source.

11/01039 Novel lithium-based sorbents from fly ashes for CO_2 capture at high temperatures

Olivares-Marín, M. *et al. International Journal of Greenhouse Gas Control*, 2010, 4, (4), 623–629.

In this work several Li_4SiO_4-based sorbents from fly ashes for CO_2 capture at high temperatures have been developed. Three fly ash samples were collected and subjected to calcination at 950 °C in the presence of Li_2CO_3. Both pure Li_4SiO_4 and fly ash-based sorbents were characterized and tested for CO_2 sorption at different temperatures between 400 and 650 °C and adding different amounts of K_2CO_3 (0–40 mol%). To examine the sorbents performance, multiple CO_2 sorption/desorption cycles were carried out. The temperature and the presence of K_2CO_3 strongly affect the CO_2 sorption capacity for the sorbents prepared from fly ashes. When the sorption temperature increases by up to 600 °C both the CO_2 sorption capacity and the sorption rate increase significantly. Moreover when the amount of K_2CO_3 increases, the CO_2 sorption capacity also increases. At optimal experimental conditions (600 °C and 40 mol% K_2CO_3), the maximum CO_2 sorption capacity for the sorbent derived from fly ash was 107 mg CO_2/g sorbent. The Li_4SiO_4-based sorbents can maintain its original capacity during 10 cycle processes and reach the plateau of maximum capture capacity in less than 15 min, while pure Li_4SiO_4 presents a continual upward tendency for the 15 min of the capture step and attains no equilibrium capacity.

Economics, business, marketing, policy

11/01040 An oil demand and supply model incorporating monetary policy

Askari, H. and Krichene, N. *Energy*, 2010, 35, (5), 2013–2021.

Oil price inflation may have had a significant role in pushing the world economy into its worst post-war recession during 2008–2009. Reserve currency central banks pursued an overly expansionary monetary policy during 2001–2009, in the form of low or negative real interest rates and accompanied by a rapidly falling US dollar, while paying inadequate attention to the destabilizing effects on oil markets. This paper shows that monetary policy variables, namely key interest rates and the US dollar exchange rate, had a powerful effect on oil markets. World oil demand was significantly influenced by interest and dollar exchange rates, while oil supply was rigid. Oil demand and supply have very low price elasticity and this characteristic makes oil prices highly volatile and subject to wider fluctuations than the prices of other commodities. Aggressive monetary policy would stimulate oil demand, however, it would be met with rigid oil supply and would turn inflationary and disruptive to economic growth if there was little excess capacity in oil output. It is argued that a measure of stability in oil markets cannot be achieved unless monetary policy is restrained and real interest rates become significantly positive. Monetary tightening during 1979–1982 might imply that monetary policy has to be restrained for a long period and with high interest rates in order to bring stability back to oil markets.

11/01041 Benefits of natural gas introduction in the energy matrix of isolated electrical system in the city of Manaus – state of Amazonas – Brazil

Frota, W. M. and Rocha, B. R. P. *Energy Policy*, 2010, 38, (4), 1811–1818.

The need to find cleaner, safer and less expensive sources of fuel in the city of Manaus, capital of the state of Amazonas (AM) in Brazil is inevitable due, among other factors, to the historical situation of the petroleum-derived fuel's large-scale use for power generation in the city by Brazil's energy planning. In this context, the use of natural gas in the province of Urucu, in the city of Coari countryside of the state of Amazons, is the best short-term solution, which will enable the substitution of petroleum-derived liquid fuels for the natural gas in the thermoelectric power plants in the city of Manaus and in seven other cities in the state, which are favoured by the Coari–Manaus pipeline's main trajectory. This article presents the economic and environmental benefits with gas natural introduction in the energy matrix of isolated electrical system in Manaus. This project will be a great conquest for the city of Manaus, as a result of the Brazilian energy sector 20-year-planning, which will be completed in 2010, and will permit the beginning of a new growth-and-development cycle for the state of Amazonas and the Amazon itself.

11/01042 China steps up use of gas

Anon., *Oil and Energy Trends*, 2010, 35, (10), 3–6.

Given the increase in energy demand within China, natural gas is being increasingly promoted as a favourable option. Natural gas is environmentally cleaner than coal and has the potential for at least some of the supply to be produced domestically. New gas-producing areas are being explored, as is unconventional gas, coal-bed methane. Imported gas will still be required and in larger quantities to keep up with demand, pipelines are being extended to allow gas to be sourced from central Asia, and there are further plans for links to Burma and Russia.

11/01043 Comparison of natural gas driven heat pumps and electrically driven heat pumps with conventional systems for building heating purposes

Brenn, J. *et al. Energy and Buildings*, 2010, 42, (6), 904–908.

Electrically driven heat pumps achieve good efficiencies for space heating. If heat pumps are driven directly by a combustion engine instead of an electric motor, losses attributed to the production and transport of electricity are eliminated. Additionally, the use of the combustion engine's heat leads to a reduced temperature difference across the heat pump. This article presents annual efficiencies of these systems and compares internal combustion engine and electrically driven heat pumps in terms of primary energy consumption and CO_2 emissions. Because heat pump performance depends strongly on the heating circuit's flow temperature level, the comparison is performed for air-to-water and geothermal heat pump systems in two cases of maximum flow temperatures (40 and 60 °C). These temperature levels represent typical modern buildings with large heating surfaces and older buildings with high-temperature radiators, respectively. In addition to the different heat pump setups, conventional space heating systems are included in the comparison. The calculations show that natural gas-driven heat pumps achieve about the same efficiency and CO_2 emissions as electrically driven heat pumps powered with electricity from the most modern natural gas-fired combined cycle power plants. The efficiency of such systems is about twice that of conventional boiler technologies.

11/01044 Conversion of individual natural gas to district heating: geographical studies of supply costs and consequences for the Danish energy system

Möller, B. and Lund, H. *Applied Energy*, 2010, 87, (6), 1846–1857.

Replacing individual natural gas heating with district heating based to increasing shares of renewable energy sources may further reduce CO_2-emissions in the Danish building mass, while increasing flexibility of the energy system to accommodate significantly larger amounts of variable renewable energy production. The present paper describes a geographical study of the potential to expand district heating into areas supplied with natural gas. The study uses a highly detailed spatial database of the built environment, its current and potential future energy demand, its supply technologies and its location relative to energy infrastructure. First, using a spatially explicit economic model, the study calculates the potentials and costs of connection to expanded district heating networks by supply technology. Then a comprehensive energy systems analysis is carried out to model how the new district heat can be supplied from an energy system with higher shares of renewable energy. It can be concluded on the basis of these analyses that the methods used proved highly useful to address issues of geographically dependent energy supply; however the spatio-economic model still is rather crude. The analyses suggest to expand district heating from present 46% to somewhere in between 50% and 70%. The most attractive potential is located around towns and cities. The study also suggests that CO_2-emissions, fuel consumption and socio-economic costs can be reduced by expanding district heating, while at the same time investing in energy savings in the building mass as well as increased district heating network efficiency.

11/01045 Dynamic pricing in the Spanish gasoline market: a tacit collusion equilibrium

García, J. P. *Energy Policy*, 2010, 38, (4), 1931–1937.

During the past 20 years, the Spanish petrol market has undergone an intensive restructuration process; it has changed from being a state-owned monopoly to total liberalization and privatization. This liberalization process was accompanied by measures that facilitated the creation of a 'national champion,' the Repsol Group, which is a huge, vertically integrated company with a high market share in all the industry's segments. Using a dynamic model, this paper analyses whether the prices established by companies in the Spanish gasoline

market, after the restructuration process, fits with a tacit collusion equilibrium. The empirical results show that a strategic behaviour of companies occurs and is compatible with a tacit collusion price strategy. So, the restructuration process does not seem to have introduced effective competition into the Spanish gasoline market.

11/01046 Formation enhancement of methane hydrate for natural gas transport and storage

Kim, N.-J. *et al. Energy*, 2010, 35, (6), 2717–2722.

Methane hydrate is considered an excellent way of transporting and storing natural gas in large quantities. However, when methane hydrate is formed artificially, water/gas ratio is relatively low due to a slow reaction rate between water and methane gas. The major objective of this study is to investigate the mechanics of methane hydrate formation and to explore possible means for rapid production of hydrates and increasing its water/gas ratio. It is found that methane hydrate could be formed rapidly during pressurization if the subcooling is maintained at 8 K or above. In addition, water injection appears to be more effective in hydrate formation compared to gas injection or using a magnetic stirrer. It also gives higher water/gas ratios of three to four times for the methane hydrate through a nozzle at the same level of subcooling temperature, when compared to gas injection cases.

11/01047 Gas-on-gas competition in Shanghai

Manuhutu, C. and Owen, A. D. *Energy Policy*, 2010, 38, (5), 2101–2106.

In common with other major economic centres in China, Shanghai's energy consumption has been increasing rapidly to support the high growth rate of its economy. To achieve rational, efficient and clean use of energy, together with improved environmental quality within the city, the Shanghai municipal government has decided to expand the supply and utilization of natural gas. Shanghai plans to increase the share of natural gas in its primary energy mix to 7% 2010, up from 3% in 2005. This increase in natural gas demand has to be matched with a corresponding increase in supply. To date, the Shanghai region has relied on offshore extracted natural gas but this supply is limited due to the size of the reserves. Since 2005, the west–east pipeline has provided an alternative for Shanghai but demands from other regions could reduce the potential for expanding supplies from that source. Since domestic production will not be sufficient to meet demand in the near future, Shanghai is building a liquefied natural gas (LNG) regasification terminal at the Yangshan deep-water port that would allow an additional supply of more than 3 billion cubic metres per year of natural gas. Malaysia has already committed to supply LNG to the Shanghai terminal at a price that is significantly higher than the wholesale 'city-gate' price for natural gas transported via pipeline, but still lower than the gas price to end-use consumers. The presence of both an LNG terminal and a transmission pipeline that connects Shanghai to domestic gas-producing regions will create gas-on-gas competition. This study assesses the benefits of introducing such competition to one of China's most advanced cities under various scenarios for demand growth. In this paper, the impact of imported LNG on market concentration in Shanghai's gas market will be analysed using the Herfindahl–Hirschmann index (HHI) and the residual supply index (RSI). The results show that Shanghai remains a supply-constrained gas market that will continue to rely upon gas supplies from the western provinces and imported LNG. After 2017, the gas market in Shanghai can be regarded as unconcentrated since its HHI fall below 1800 under a very high growth scenario. In terms of RSI, the gas market can be considered competitive at low, moderate and high growth consumption between 2012 and 2015.

11/01048 Hedging strategy for crude oil trading and the factors influencing hedging effectiveness

Yun, W.-C. and Kim, H. J. *Energy Policy*, 2010, 38, (5), 2404–2408.

This study analyses the hedging effectiveness of different hedge type and period by Korean oil traders. Both crude oil price and exchange rate risks are considered. Theoretical models are formulated to estimate the hedge ratios by separate and complex hedge types. The hedging period covers 1–12 months. This study also performs some statistical works to investigate the relationship between the hedging effectiveness and the crude oil price sensitivity to exchange rate. In addition, the relationship between the hedging effectiveness and the volatilities of crude oil price and exchange rate is analysed.

11/01049 How does increased corn-ethanol production affect US natural gas prices?

Whistance, J. and Thompson, W. *Energy Policy*, 2010, 38, (5), 2315–2325.

In recent years, there has been a push to increase biofuel production in the USA. The biofuel of choice, so far, has been ethanol produced from corn. The effects of increased corn-ethanol production on the consumer prices of food and energy continue to be studied and debated. This study examines, in particular, the effects of increased corn-ethanol production on US natural gas prices. A structural model of the natural gas market is developed and estimated using two-stage least squares. A baseline projection for the period 2007–2018 is determined, and two scenarios are simulated. In the first scenario, current biofuel policies including EISA mandates, tariffs, and tax credits are removed. In the second scenario, ethanol production is held to the level required only for largely obligatory additive use. The results indicate that the increased level of corn-ethanol production occurring as a result of the current US biofuel policies may lead to natural gas prices that are as much as 0.25% higher, on average, than if no biofuel policies were in place. A similar comparison between the baseline and second scenario indicates natural gas prices could be as much as 0.5% higher, on average, for the same period.

11/01050 Methane microseepage from different sectors of the Yakela condensed gas field in Tarim Basin, Xinjiang, China

Tang, J. *et al. Applied Geochemistry*, 2010, 25, (8), 1257–1264.

Methane microseepage is the result of natural gas migration from subsurface hydrocarbon accumulations to the Earth's surface, and it is quite common in commercial petroleum fields. While the role of microseepage as a pathfinder in petroleum exploration has been known for about 80 years, its significance as an atmospheric CH_4 source has only recently been studied, and flux data are currently available only in the USA and Europe. With the aim of increasing the global data-set and better understanding flux magnitudes and variabilities, microseepage is now being extensively studied in China. A static flux chamber method was recently applied to study microseepage emissions into the atmosphere in four different sectors of the Yakela condensed gas field in Tarim Basin, Xinjiang, China, and specifically in: (a) a faulted sector, across the Luntai fault systems; (b) an oil–water interface sector, at the northern margin of the field; (c) an oil–gas interface sector, in the middle of the field; (d) an external area, outside the northern gas field boundaries. The results show that positive CH_4 fluxes are pervasive in all sectors and therefore, only part of the CH_4 migrating from the deep oil–gas reservoirs is consumed in the soil by methanotrophic oxidation. The intensity of gas seepage seems to be controlled by subsurface geologic settings and lateral variabilities of natural gas pressure in the condensed gas field. The highest CH_4 fluxes, up to $\sim$14 mg m^{-2} d^{-1} (mean of 7.55 mg m^{-2} d^{-1}) with higher spatial variability (standard deviation, σ: 2.58 mg m^{-2} d^{-1}), occur in the Luntai fault sector. Merhane flux was lower in the oil–water area (mean of 0.53 mg m^{-2} d^{-1}) and the external area (mean of 1.55 mg m^{-2} d^{-1}), and at the intermediate level in the gas–oil sector (mean of 2.89 mg m^{-2} d^{-1}). These values are consistent with microseepage data reported for petroleum basins in the USA and Europe. The build-up of methane concentration in the flux chambers is always coupled with an enrichment of ^{13}C, from $\delta^{13}C_1$ of -46‰ to -42.5‰ (VPDB), which demonstrates that seeping methane is thermogenic, as that occurring in the deep Yakela reservoir. Daily variations of microseepage are very low, with minima in the afternoon, corresponding to higher soil temperature (and higher methanotrophic consumption), and maxima in the early morning (when soil temperatures are lowest). A preliminary and rough estimate of the total amount of CH_4 exhaled from the Yakela field is in the order of 10^2 tonnes a^{-1}. The present data can statistically improve the accuracy of the global microseepage flux data-set, but further surveys are needed in order to understand the frequency of occurrence and spatial variability of positive CH_4 fluxes in soils over petroleum fields.

11/01051 Symbolic convergence and the hydrogen economy

Sovacool, B. K. and Brossmann, B. *Energy Policy*, 2010, 38, (4), 1999–2012.

This article documents that the hydrogen economy continues to attract significant attention among politicians, the media, and some academics. The authors believe that an explanation lies in the way that the hydrogen economy fulfils psychological and cultural needs related to a future world where energy is abundant, cheap, and pollution-free, a 'fantasy' that manifests itself with the idea that society can continue to operate without limits imposed by population growth and the destruction of the environment. The article begins by explaining its research methodology consisting of two literature reviews, research interviews of energy experts, and the application of symbolic convergence theory, a general communications theory about the construction of rhetorical fantasies. Socio-technical challenges are identified to explain why the creation of a hydrogen economy would present immense (and possibly intractable) obstacles, an argument supplemented by research interviews. Next, symbolic convergence theory is used to identify five prevalent fantasy themes and rhetorical visions – independence, patriotism, progress, democratization, and inevitability – in academic and public discussions in favour of the hydrogen economy. The paper concludes by offering implications for scholarship relating to energy policy more broadly.

Derived gaseous fuels

11/01052 A simple robust controller for power maximization of a variable-speed wind turbine

Evangelista, C. *et al. International Journal of Energy Research*, 2010, 34, (10), 924–932.

This paper presents a high-order sliding mode control strategy that aims to optimize the power conversion efficiency of a wind energy conversion system within the partial load zone of operation. The main challenges of this control problem are related to the random variations of the wind speed, the non-linear nature of the whole system, usual model uncertainties and external disturbances. For all these reasons, the robustness, simplicity and low computational burden of the proposed super-twisting algorithm result very attractive in this context. Simulation results that show the desired characteristics are acheived.

11/01053 An experimental study of syn-gas production via microwave plasma reforming of methane, iso-octane and gasoline

Kim, T.-S. *et al. Energy*, 2010, 35, (6), 2734–2743.

A newly developed microwave plasma system for fuel reforming was tested for three different hydrocarbon fuels. The microwave plasma system was powered by a low cost commercial magnetron and power supply. The microwave power was delivered to the nozzle from the magnetron via a coaxial cable, which offers tremendous flexibility for system design and applications. A non-premixed configuration was achieved by delivering a separate stream of fuel to the plasma plume, which is composed of diluted oxygen only. The feasibility of syn-gas production capability of the microwave plasma system was demonstrated and the reforming characteristics of methane, iso-octane and gasoline were compared. The effects of input power, injected fuel amount, total flow rate and O/C ratio were evaluated. The production rates of both hydrogen and carbon monoxide were proportional to the input power and the inverse of the total flow rate. As a result, the maximum efficiency of 3.12% was obtained with iso-octane for power consumption of 28.8 W, O/C ratio of 1, and 0.1 g/min of fuel supply. Liquid fuels produced more syn-gas and showed better efficiency than methane for the same input powers and O/C ratios.

11/01054 Catalytic characteristics of carbon black for decomposition of ethane

Lee, S. Y. *et al. Carbon*, 2010, 48, (7), 2030–2036.

The catalytic activities of rubber, colour and conductive carbon black catalysts for decomposition of ethane were investigated in the temperature range from 973 to 1173 K. Significantly higher ethane conversion and lower ethylene selectivity were obtained in the presence of carbon black catalysts compared with non-catalytic decomposition, resulting in much higher hydrogen yields. This indicates that carbon black catalysts are effective catalysts for dehydrogenation of ethane to hydrogen and ethylene, as well as for the subsequent decomposition of ethylene to hydrogen and solid carbon. However, more methane was produced in the presence of carbon black catalysts than in non-catalytic decomposition. A reaction mechanism was proposed for the catalytic decomposition of ethane. The hydrogen yield increased with an increase in the specific surface area of the non-porous rubber and colour carbon black catalysts with a surface area of up to approximately 100 m^2/g. However, the hydrogen yield over the carbon black catalysts with higher surface areas, including the conductive carbon black catalysts with very high surface areas, did not increase significantly. The carbon black catalysts exhibited stable activity for ethane decomposition and hydrogen production for 36 h despite carbon deposition.

11/01055 Catalytic dehydration of methanol to dimethyl ether over mordenite catalysts

Moradi, G. R. *et al. Fuel Processing Technology*, 2010, 91, (5), 461–468.

The conversion of methanol to dimethyl ether was carried out over various commercial mordenite and ion-exchanged catalysts to evaluate the catalytic performance of mordenite catalysts with different pore structures and acidities. These catalysts were compared for their catalytic properties in a fixed-bed reactor at 1 atm, 573 K and LHSV of 2.84 h^{-1}. The catalysts were characterized by BET, ICP, NH_3-TPD, XRD, TGA and FT-IR techniques. The ion-exchanged mordenite showed higher activity, selectivity and good stability in dehydration of methanol due to the addition of medium acid sites. Also, the effect of water on catalyst deactivation was investigated over two selected catalysts in order to develop a suitable catalyst for synthesis of dimethyl ether. It was found that the H-mordenite catalyst supplied by Süd-chemie Co., (MCDH-1) was more active and less deactivated than another one in a feed containing 20 wt% water.

11/01056 Development of platinum-based bimodal pore catalyst for CO_2 reforming of CH_4

Tao, K. *et al. Catalysis Today*, 2010, 153, (3–4), 150–155.

The synthesis and preparation conditions for bimodal pore catalyst support were studied. SiO_2–SiO_2, ZrO_2–SiO_2, or Al_2O_3–SiO_2 bimodal pore support could be optimally prepared by incipient-wetness impregnation (IWI) of silica Q-50 pellet with silica, zirconia or alumina sol, respectively. Pore size measurement results suggested that the obtained bimodal pore supports showed two kinds of pores, mesopores and original macropores, simultaneously. The newly formed mesopores contributed to the increased BET surface area of bimodal pore support, compared with that of the original silica Q-50. Pt catalysts supported on these kinds of supports were tested in CO_2 reforming of CH_4. The performances of Pt/ZrO_2–SiO_2 and Pt/Al_2O_3–SiO_2 bimodal pore catalysts were better. Furthermore, it was found that Pt/Al_2O_3–SiO_2 bimodal catalyst showed better reforming performance than Pt/ZrO_2–SiO_2 bimodal catalyst. And furthermore, CeO_2 modified Pt/Al_2O_3–SiO_2 bimodal pore catalyst exhibited highest activity and stability under the present study conditions.

11/01057 Fischer–Tropsch synthesis and the generation of DME *in situ*

Zonetti, P. C. *et al. Fuel Processing Technology*, 2010, 91, (5), 469–475.

Ternary physical mixtures comprised a Fischer–Tropsch catalyst, a methanol synthesis catalyst and a zeolite employed in the hydrocarbon synthesis from syngas. Two Fe-based catalysts (i.e. one promoted by K and the other by Ru), two HY zeolites with different acidities, a commercial HZSM-5 and Cu/ZnO/Al_2O_3 (methanol synthesis catalyst) were used in these systems. The main products obtained were dimethyl ether, methanol and hydrocarbons. First of all, it was observed that by adding Cu/ZnO/Al_2O_3 catalyst to a binary physical mixture comprised of a Fischer–Tropsch catalyst and HZSM-5, the CO conversion increases more than 20 times. Second, during the reaction transient period the dimethyl ether selectivity decreases as the conversion increases. Third, the hydrocarbons synthesized followed the ASF distribution in the C_1–C_{12} range and finally, it was also verified that the Y zeolites and the Fischer–Tropsch synthesis catalyst promoted by Ru generated the most active physical mixtures. The results showed that the role of zeolites in the ternary physical mixture is only associated with the dimethyl ether synthesis. The following reaction pathway was suggested: first, methanol is synthesized from syngas using Cu/ZnO/Al_2O_3 catalyst; after that, this alcohol is dehydrated by an acid catalyst generating DME; and lastly, DME initiates Fischer–Tropsch synthesis, which is then propagated by CO.

11/01058 Highly efficient synthesis of dimethyl ether from syngas over the admixed catalyst of CuO–ZnO–Al_2O_3 and antimony oxide modified HZSM-5 zeolite

Mao, D. *et al. Energy Conversion and Management*, 2010, 51, (6), 1134–1139.

A series of HZSM-5 zeolites modified with various contents of antimony oxide (0–30 wt%) were prepared by solid state ion reaction at 500 °C, and the acidities of the resulted materials were characterized by temperature-programmed desorption of NH_3. The direct synthesis of dimethyl ether (DME) from syngas was carried out over the admixed catalysts of an industrial CuO–ZnO–Al_2O_3 methanol synthesis catalyst and the parent and antimony oxide modified HZSM-5 zeolites under pressurized fixed-bed continuous flow conditions. The results indicated that modification of HZSM-5 with suitable amount of antimony oxide significantly decreased the selectivity for undesired byproducts like hydrocarbons and carbon dioxide from 9.3% and 32.4% to less than 1% and 28%, respectively, so the selectivity for DME was enhanced greatly from 55% to 69% under temperature of 260 °C, pressure of 4 MPa and gas hourly space velocity of 1500 mL h^{-1} G_{cat}^{-1}. The decrease in the formation of hydrocarbons and carbon dioxide can be attributed to the significant decline in the amount of strong acid sites of the HZSM-5 zeolite induced by antimony oxide modification. Additionally, the influences of the operating parameters on the performance of the most efficient catalyst were also investigated. The results showed that high reaction temperature and high gas hourly space velocity resulted in both lower carbon monoxide conversion and lower dimethyl ether selectivity, so they should be no higher than 280 °C and 3000 mL h^{-1} G_{cat}^{-1}, respectively.

11/01059 Methane hydrates as potential energy resource: part 1 – importance, resource and recovery facilities

Demirbas, A. *Energy Conversion and Management*, 2010, 51, (7), 1547–1561.

Gas hydrates are ice-like crystalline solids that form from mixtures of water and light natural gases such as methane, carbon dioxide, ethane, propane and butane. Methane was the dominant component among other hydrocarbon gases in the sediments. Gas hydrates, potentially one of the most important energy resources for the future. Methane gas hydrates are increasingly considered a potential energy resource. Enormous reserves of hydrates can be found under continental shelves

and on land under permafrost. Gas hydrate or clathrate consists of three general structure types. Depending on the size of the guest molecule, natural gas hydrates can consist of any combination of three crystal structures: (1) structure I or sI, (2) structure II or sII and (3) structure H or sH. When pure liquid water freezes it crystallizes with hexagonal symmetry, but when it 'freezes' as a hydrocarbon hydrate it does so with cubic symmetry for sI and sII, reverting to hexagonal symmetry for sH. Methane hydrates are widespread in sea sediments hundreds of meters below the sea floor along the outer continental margins and are also found in Arctic permafrost. Some deposits are close to the ocean floor and at water depths as shallow as 150 m, although at low latitudes they are generally only found below 500 m. The deposits can be 300–600 m thick and cover large horizontal areas. Hydrates may affect climate because when warmed or depressurized, they decompose and dissociate into water and methane gas, one of the greenhouse gases that warms the planet. Methane is a greenhouse gas. Discharge of large amounts of methane into the atmosphere would cause global warming. Methane hydrates hold the danger of natural hazards associated with sea floor stability, release of methane to ocean and atmosphere and gas hydrates disturbed during drilling pose a safety problem.

11/01060 Methane hydrates as potential energy resource: part 2 – methane production processes from gas hydrates

Demirbas, A. *Energy Conversion and Management*, 2010, 51, (7), 1562–1571.

Three processes have been proposed for dissociation of methane hydrates: thermal stimulation, depressurization, and inhibitor injection. The obvious production approaches involve depressurization, heating and their combinations. The depressurization method is lowering the pressure inside the well and encouraging the methane hydrate to dissociate. Its objective is to lower the pressure in the free-gas zone immediately beneath the hydrate stability zone, causing the hydrate at the base of the hydrate stability zone to decompose. The thermal stimulation method is applied to the hydrate stability zone to raise its temperature, causing the hydrate to decompose. In this method, a source of heat provided directly in the form of injected steam or hot water or another heated liquid, or indirectly via electric or sonic means. This causes methane hydrate to decompose and generates methane gas. The methane gas mixes with the hot water and returns to the surface, where the gas and hot water are separated. The chemical inhibition method seeks to displace the natural-gas hydrate equilibrium condition beyond the hydrate stability zone's thermodynamic conditions through injection of a liquid inhibitor chemical adjacent to the hydrate. In this method, inhibitor such as methanol is injected from surface down to methane hydrate-bearing layers. The thermal stimulation method is quite expensive. The chemical inhibitor injection method is also expensive. The depressurization method may prove useful to apply more than one production.

11/01061 Production of synthetic natural gas (SNG) from coal and dry biomass – a technology review from 1950 to 2009

Kopyscinski, J. *et al. Fuel*, 2010, 89, (8), 1763–1783.

Synthetic natural gas (SNG) production from coal or biomass is considered again due to rising prices for natural gas, the wish for less dependency from natural gas imports and the opportunity of reducing green house gases by CO_2 capture and sequestration. Coal and solid dry biomass (e.g. wood and straw) have to be converted to SNG by thermochemical processes (gasification followed by gas cleaning, conditioning, methanation of the producer gas and subsequent gas upgrading). During the 1970s, a number of methanation processes have been developed comprising both fixed bed and fluidized bed methanation. Meanwhile several new processes are under development, especially with a focus on the conversion of biomass. While coal-based systems usually involve high pressure cold gas cleaning steps, biomass-based systems require, due to the smaller unit size, different gas cleaning strategies. Moreover, the ethylene content of a few percent, typical for methane-rich producer gas from biomass gasifiers, is a challenge for the long-term catalyst stability in adiabatic fixed bed methanation due to the inherent high temperatures. This paper reviews the processes developed for the production of SNG from coal during the 1960s and 1970s and the recent developments for SNG production from coal and from dry biomass.

11/01062 Synthesis of carbon-supported nickel catalysts for the dry reforming of CH_4

Fidalgo, B. *et al. Fuel Processing Technology*, 2010, 91, (7), 765–769.

A series of carbon-based nickel (Ni) catalysts was prepared in order to investigate the effect of the preparation method on the dispersion of Ni and its final catalytic activity in the dry reforming of methane, i.e. $CH_4 + CO_2 = 2H_2 + 2CO$. Three parameters were studied: (i) the influence of the surface chemistry of the carbon used as support; (ii) the method of drying (conventional *vs*. microwave drying); and (iii) the temperature of the reduction stage. In order to study the role of the surface chemistry of the commercial activated carbon used as support, the active carbon was tested as received and oxidized. Although a better Ni dispersion was achieved over the oxidized support, the conversions were much lower. It was also found that microwave drying offers various advantages over conventional drying, the main one being that less time is required to prepare the catalyst. Two reduction temperatures were used (300 and 500 °C), being found that it is necessary to adjust this parameter to prevent the Ni particles from sintering.

LNG

11/01063 Cold recovery during regasification of LNG part one: cold utilization far from the regasification facility

La Rocca, V. *Energy*, 2010, 35, (5), 2049–2058.

The paper deals with cold recovery during LNG regasification. The applications analysed pertain to the use in deep freezing agro food industry and in space air conditioning facilities in commercial sector (supermarkets and hypermarkets) of cold recovered from the regasification process. A modular LNG regasification unit is proposed having the regasification capacity of 2 BCM/year of gas and it is based on use of a power cycle working with ethane, this unit allows operation of cold energy transfer, contained in LNG to be regasified, in a range of temperatures suitable for multipurpose use of cold, reducing regasification process irreversibility. Some electric energy is produced by the power cycle, but the purpose of the modular unit is to deliver cold suitable for industrial and commercial use in the proper temperature range utilizing carbon dioxide as secondary fluid to transfer cold from regasification site to far end users. The subject is divided in two papers: this paper deals with facilities delivering cold released during LNG regasification and related pipeline facilities to transfer cold at far end users while the other paper pertains to analysis of end users applications. Results of a detailed thermodynamic and economic analysis demonstrate the suitability of the proposal.

11/01064 Experimental study on liquid/solid phase change for cold energy storage of liquefied natural gas (LNG) refrigerated vehicle

Tan, H. *et al. Energy*, 2010, 35, (5), 1927–1935.

The present paper addresses an experimental investigation of the cold storage with liquid/solid phase change of water based on the cold energy recovery of liquefied natural gas (LNG) refrigerated vehicles. Water as a phase change material was solidified outside the heat transfer tubes that were internally cooled by cryogenic nitrogen gas substituting cryogenic natural gas. The ice layer profiles were recorded in different cross-sections observed by digital cameras. The temperatures of cryogenic gas, tube wall and bulk region were measured by embedded thermocouples continuously. The results of the smooth tube experiments and the thermal resistance analysis prove that the main thermal resistance occurs in the gaseous heat transfer fluid inner the tube. The enhancement of the inner heat transfer is achieved by adding wave-like internal fins. Besides, the results show that the ice layer not only increases in radial direction but also propagates in axial direction. It distributes in parabolic shape along the tube length due to the parabolic axial distribution of the tube wall temperatures. This investigation provides valuable references for the design and optimization of the cold energy storage unit of LNG refrigerated vehicles and for the numerical study on the unsteady two-dimensional conjugated heat transfer with phase change.

11/01065 Life-cycle greenhouse gas analysis of LNG as a heavy vehicle fuel in Europe

Arteconi, A. *et al. Applied Energy*, 2010, 87, (6), 2005–2013.

The aim of the present study was to compare the life cycle, in terms of greenhouse gas (GHG) emissions, of diesel and liquefied natural gas (LNG) used as fuels for heavy-duty vehicles in the European market (EU-15). A literature review revealed that the numerous studies conducted have reported different results when the authors departed from different baseline assumptions and reference scenarios. This study concentrated on the European scenario and on heavy-duty road transport vehicles, given their important incidence on the global emissions of GHG. Two possible LNG procurement strategies were considered i.e. purchasing it directly from the regasification terminal (LNG-TER) or producing LNG locally (at the service station) with small-scale plants (LNG-SSL). The authors ascertained that the use of LNG-TER enables a 10% reduction in GHG emissions by comparison with diesel, while the emissions resulting from the LNG-SSL solution are comparable with those of diesel.

Hydrogen generation and storage

11/01066 Design of filament-wound circular toroidal hydrogen storage vessels based on non-geodesic fiber trajectories

Zu, L. *et al. International Journal of Hydrogen Energy*, 2010, 35, (2), 660–670.

One of the most important design issues for filament-wound hydrogen storage vessels reflects on the determination of the optimal winding trajectories. The goal of this paper is to determine the optimal fibre paths and the resulting laminated structures for non-geodesically overwound circular toroidal hydrogen storage vessels. With the aid of the continuum theory and the non-geodesic law, the differential equations describing non-geodesic paths on a toroidal surface are given. The general criteria for avoiding fibre-bridging and slippage on a torus are formulated by differential geometry. The relation between the slippage coefficient and the winding angle is obtained to meet stable winding requirements. The initial winding angle and the slippage coefficient of non-geodesics are considered as the design variables, while the minimum shell mass acts as the objective function. The optimal non-geodesic trajectories, corresponding to various relative bending radii, are determined in order to evaluate the effect of non-geodesics on the structural performance of toroids. Results indicate that circular toroidal vessels designed using the present method show better performance than geodesics-based ones, mainly triggered by maximum utilization of the laminate strength. The results also reveal that the structural efficiency of circular toroidal vessels can be significantly improved using non-geodesic winding.

11/01067 Effects of dark/light bacteria ratio on bio-hydrogen production by combined fed-batch fermentation of ground wheat starch

Kargi, F. and Ozmihci, S. *Biomass and Bioenergy*, 2010, 34, (6), 869–874.

Bio-hydrogen production by combined dark and light fermentation of ground wheat starch was investigated using fed-batch operation. Serum bottles containing heat-treated anaerobic sludge and a mixture of *Rhodobacter* sp. was fed with a medium containing 20 g dm^{-3} wheat powder (WP) at a constant flow rate. The system was operated at different initial dark/light biomass ratios (D/L). The optimum D/L ratio was 1/2 yielding the highest cumulative hydrogen (1548 cm^3), yield (65.2 $cm^3\,g^{-1}$ starch), and specific hydrogen production rate (5.18 $cm^3\,g^{-1}\,h^{-1}$). Light fermentation alone yielded higher hydrogen production than dark fermentation due to fermentation of volatile fatty acids (VFAs) to H_2 and CO_2. The lowest hydrogen formation was obtained with D/L ratio of 1/1 due to accumulation of VFAs in the medium.

11/01068 Experimental evidence of an upper limit for hydrogen storage at 77 K on activated carbons

Fierro, V. *et al. Carbon*, 2010, 48, (7), 1902–1911.

An upper limit for hydrogen storage at 77 K on activated carbons was observed in the present experimental work. Such a limit is around 6.4 wt%, i.e. close to the theoretical limit of 6.8 wt%. Results of hydrogen storage were obtained in three independent laboratories using volumetric and gravimetric devices. Lab-made activated carbons (ACs) were found to have higher capacities than those of the commercial material AX-21. A maximum excess hydrogen storage capacity of 6.0 wt% at 77 K and 4 MPa was obtained. This maximum was reduced to 0.6 wt% at 298 K and 5 MPa. ACs with surface areas (S_{BET}) as high as 3220 $m^2\,g^{-1}$ were prepared from chemical activation of anthracites with alkali (Na and K) hydroxides. At 77 K and 4 MPa, excess hydrogen storage capacity was directly correlated with S_{BET} for ACs having S_{BET} values lower than 2630 m^2/g. Hydrogen uptake at 77 K also correlated with micropore volume and strongly depended on average pore diameter.

11/01069 Factorial design of experiment (DOE) for parametric exergetic investigation of a steam methane reforming process for hydrogen production

Hajjaji, N. *et al. Chemical Engineering and Processing: Process Intensification*, 2010, 49, (5), 500–507.

Hydrogen is expected to play a significant role in future energy systems. The efficient production of hydrogen at a minimum cost and in an environmentally acceptable manner is crucial for the development of a hydrogen-including economy. The exergy analysis is a powerful tool to quantify sustainable development potential. An important aspect of sustainable development is minimizing irreversibility. The purpose of this study is to perform the exergy analysis of a steam methane reforming (SMR) process for hydrogen production. As a first step, an exergy analysis of an existing process is shown to be an efficient tool to critically examine the process energy use and to test for possible savings in primary energy consumption. The results of this investigation prove that the exergetic efficiency of the SMR process is 65.47%, and the majority of destroyed exergy is localized in the reformer with a 65.81% contribution to the whole process destroyed exergy. Next, an exergetic parametric study of the SMR has been carried out with a factorial design of experiment (DOE) method. The influence of the reformer operating temperature and pressure and of the steam to carbon ratio (S/C) on the process exergetic efficiency has been studied. A second-order polynomial mathematical model has been obtained through correlating the exergetic efficiencies with the reformer operating parameters. The results of this study show that the rational choice of these parameters can improve the process exergetic performance.

11/01070 High-pressure hydrogen storage on microporous zeolites with varying pore properties

Chung, K.-H. *Energy*, 2010, 35, (5), 2235–2241.

Hydrogen storage on microporous zeolites was examined using a high pressure dose of hydrogen at 30 °C. The roles of the framework structure, surface area, and pore volume of the zeolites on hydrogen adsorption were investigated. The largest hydrogen storage was obtained on the ultra stable Y (USY) zeolite (0.4 wt%). The hydrogen adsorption isotherms on the zeolites reached a maximum after a hydrogen pressure of 50 bar. The amount of hydrogen adsorption on Mordenite (MOR) zeolites increased with increasing Si/Al molar ratio, which was achieved by dealumination. The amount of hydrogen adsorption increased linearly with increasing pore volume of the zeolites. The hydrogen adsorption behaviour was found to be dependent mainly on the pore volume of the zeolites.

11/01071 Hydrogen production from acetate in a cathode-on-top single-chamber microbial electrolysis cell with a mipor cathode

Guo, K. *et al. Biochemical Engineering Journal*, 2010, 51, (1–2), 48–52.

A cathode-on-top single-chamber microbial electrolysis cell (MEC) was constructed by putting the cathode above the anode. The cathode was made of mipor titanium tube coated with platinum and the anode was graphite granules with exoelectrogens absorbed on its surface. Sodium acetate was used as the substrate. In 24 h batch tests, when the applied voltages increased from 0.2 V to 1.0 V with an interval of 0.1 V, the hydrogen production rates increased from 0.03 L/L/d to 1.58 L/L/d, and the overall hydrogen recoveries increased from 26.03% to 87.73%. The maximum overall energy recovery was 86.78% when the applied voltage was 0.6 V. Meanwhile, hydrogen production was accompanied by evolution of methane, and the main methane producer in this MEC was hydrogenotrophic methanogens. The methane production rate increased with the increase of the hydrogen production rate when the applied voltage was under 0.5 V; however, it maintained approximately 0.04 L/L/d when the applied voltage was above 0.5 V. These results demonstrate that putting the cathode above the anode is able to increase the hydrogen recoveries but also obtain high hydrogen production rates. These results also demonstrate that operating this MEC at a relative higher voltage (>0.6 V) is able to reduce methane production and improve the hydrogen recovery in 24 h batch tests.

11/01072 Hydrogen production from urea wastewater using a combination of urea thermal hydrolyser–desorber loop and a hydrogen-permselective membrane reactor

Rahimpour, M. R. *et al. Fuel Processing Technology*, 2010, 91, (6), 600–612.

This work presents novel application of palladium-based membrane in a wastewater treatment loop of urea plant for hydrogen production. Urea wastewater treatment loop is based on combined thermal hydrolysis–desorption operations. The wastewater of urea plant includes ammonia and urea which in the current treatment loop; urea decomposes to ammonia and carbon dioxide. The catalytic hydrogen-permselective membrane reactor is proposed for hydrogen production from desorbed ammonia of urea wastewater which much of it discharges to air and causes environmental pollution. Therefore hydrogen is produced from decomposition of ammonia on nickel–alumina catalyst bed simultaneously and permeates from reaction side to shell side through thin layer of palladium–silver membrane. Also a sweep gas is used in the shell side for increasing driving force. In this way, 4588 tons/year hydrogen is produced and environmental problem of urea plant is solved. The membrane reactor and urea wastewater treatment loop are modelled mathematically and the predicted data of the model are consistent with the experimental and plant data that show validity of the model. Also the effects of key parameters on the performance of catalytic hydrogen-permselective membrane reactor such as the temperature, pressure, thickness of Pd–Ag layer, configuration of flow and sweep gas flow ratio were examined.

11/01073 Hydrogen production of the hyperthermophilic eubacterium, *Thermotoga neapolitana* under N_2 sparging condition

Nguyen, T.-A. D. *et al. Bioresource Technology*, 2010, 101, (S1), S38–S41.

Gas sparging was found to be a useful technique to reduce hydrogen partial pressure in the liquid phase to enhance the hydrogen yields of strictly anaerobically fermentative bacteria. The effect of nitrogen (N_2) sparging on hydrogen yield was investigated in sterile and non-sterile conditions using a pure strain of the hyperthermophilic eubacteria, *Thermotoga neapolitana* with glucose or xylose as a carbon source. The maximum hydrogen accumulations reached 41% of the gaseous mixtures after 30–40 h. Two applications of N_2 sparging after the H_2 content in the headspace reached the maximum levels gave an increase of H_2 production by 78% from 1.82 to 3.24 mol H_2/mol glucose and by 56% from 1.41 to 2.20 mol H_2/mol xylose. This result suggested that the removal of the produced H_2 from the gas headspace of the limited-volume, closed culture vial when it achieves the maximum level of H_2 tolerance of the bacterium is a necessary technique to improve its H_2 yield.

11/01074 H_2 storage on single- and multi-walled carbon nanotubes

Ioannatos, G. E. and Verykios, X. E. *International Journal of Hydrogen Energy*, 2010, 35, (2), 622–628.

The adsorption of hydrogen on single-walled and multi-walled carbon nanotubes (CNTs) was investigated at 77 and 298 K, in the pressure range of 0–1000 Torr. The adsorption isotherms indicate that adsorption follows the Langmuir model. Hydrogen uptakes were found to depend strongly on the nature of the CNTs. Single-walled CNTs adsorb significantly higher quantities of hydrogen per unit mass of the solid, while the opposite is true on a per unit surface area basis. This observation implies that adsorption takes place selectively on specific sites on the surface. The hydrogen uptake capacity of CNTs was also found to be affected by the purity of the materials, increasing with increasing purity. Temperature programmed desorption indicated that relatively strong adsorption bonds develop between adsorbent and adsorbate and that a single type of adsorption site exists on the solid surface.

11/01075 The synthesis and characterization of a super-activated carbon containing substitutional boron (BC_x) and its applications in hydrogen storage

Jeong, Y. and Chung, T. C. M. *Carbon*, 2010, 48, (9), 2526–2537.

A new family of porous boron-substituted carbon (BC_x) materials with controlled structure is investigated. The chemistry involves a B-precursor polymer, i.e. poly(borachlorophenyldiacetylene), containing inorganic additives (templates). At pyrolysis $<400\,^{\circ}C$, the B-precursor engages in easy inter-chain reactions to form dark solid with high yield ($>85\%$). Above $600\,^{\circ}C$, the amorphous carbon-like BC_x materials containing up to 12% B have been prepared, which show an extended fused hexagonal ring structure with B-puckered curvature. This out of planar B moiety maintains its electron deficiency, due to limited π-electron delocalization, and exhibits super-activated properties to enhance H_2 binding energy (20–10 kJ/mol) and adsorption capacity. After removing the inorganic additives by water-washing, the resulting porous BC_x shows a surface area 500–800 m^2/g. Evidently, the pore size distribution is directly related to melting temperature and distribution of the inorganic salts. As the temperature increases to $>1400\,^{\circ}C$, the distorted ring structure gradually flatten out to form a multi-layer (crystalline) BC_x structure. The resulting planar graphitic layer only can accommodate a reduced B content ($<3\%$ at $1800\,^{\circ}C$) and low surface area. The B moieties also lose their acidity due to the extensive π-electron delocalization.

11/01076 Visible light induced hydrogen evolution on new hetero-system $ZnFe_2O_4/SrTiO_3$

Boumaza, S. *et al. Applied Energy*, 2010, 87, (7), 2230–2236.

The physical properties and photoelectrochemical characterization of the spinel $ZnFe_2O_4$, elaborated by chemical route, have been investigated for the hydrogen production under visible light. The forbidden band is found to be 1.92 eV and the transition is indirectly allowed. The electrical conduction occurs by small polaron hopping with activation energy of 0.20 eV. *p*-type conductivity is evidenced from positive thermopower and cathodic photocurrent. The flat band potential (0.18 V_{SCE}) determined from the capacitance measurements is suitably positioned with respect to H_2O/H_2 level ($-0.85\,V_{SCE}$). Hence, $ZnFe_2O_4$ is found to be an efficient photocatalyst for hydrogen generation under visible light. The photoactivity increases significantly when the spinel is combined with a wide band gap semiconductor. The best performance with a hydrogen rate evolution of 9.2 $cm^3\,h^{-1}$ (mg catalyst)$^{-1}$ occurs over the new hetero-system $ZnFe_2O_4/SrTiO_3$ in $Na_2S_2O_3$ (0.025 M) solution.

11/01077 Visible-light photocatalytic hydrogen production from ethanol–water mixtures using a Pt–CdS–TiO_2 photocatalyst

Strataki, N. *et al. Catalysis Today*, 2010, 151, (1–2), 53–57.

Hydrogen was produced by photocatalytic treatment of water–ethanol mixtures. Nanocrystalline titania films, made of commercial Degussa P25, were deposited on transparent conductive glass slides (electrodes) bearing a fluorine-doped tin oxide (FTO) layer. The titania film covered two-thirds of the area of the electrode. On the remaining one-third of the area, Pt was deposited by solution casting. Finally, CdS was deposited on nanocrystalline titania. This configuration, which, in reality acts as a photoelectrochemical cell with short-circuited anode and cathode, was used to photocatalytically treat water–ethanol mixtures and produce hydrogen under visible-light irradiation. The conductive substrate was necessary to drain photogenerated electrons and channel them to the Pt-covered area where reduction interactions took place. The CdS/n-TiO_2 was necessary for visible-light response. Spatial separation of Pt from CdS/n-TiO_2 was chosen because the mixture of all three agents, i.e. titania, CdS and Pt was found incompatible. In the absence of ethanol, hydrogen production was very slow. In the presence of ethanol, the quantity of hydrogen increased by about an order of magnitude.

04 BY-PRODUCTS RELATED TO FUELS

11/01078 Abundances and distribution of minerals and elements in high-alumina coal fly ash from the Jungar power plant, Inner Mongolia, China

Dai, S. *et al. International Journal of Coal Geology*, 2010, 81, (4), 320–332.

The fly ash from the Jungar power plant, Inner Mongolia, China, is unique because it is highly enriched in alumina ($Al_2O_3 > 50\%$). The fly ash mainly consists of amorphous glass and mullite and trace amounts of corundum, quartz, char, calcite, K-feldspar, clay minerals, and Fe-bearing minerals. The mullite content in fly ash is as high as 37.4% because of high boehmite and kaolinite contents in feed coal. Corundum is a characteristic mineral formed during the combustion of boehmite-rich coal. Samples from the economizer were sieved into six size fractions (<120, 120–160, 160–300, 300–360, 360–500, and >500 mesh) and separated into magnetic, mullite + corundum + quartz (MCQ) and glass phases for mineralogical and chemical analysis. The corundum content increases but amorphous glass decreases with decreasing particle size. Fractions of small particle sizes are relatively high in mullite, probably because mullite was formed from fine clay mineral particles under high-temperature combustion condition. Similarly, fine corundum crystals formed in the boiler from boehmite in feed coal. The magnetic phase consists of hematite, magnetite, magnesioferrite, and $MgFeAlO_4$ crystals. The MCQ phase is composed of 89% mullite, 6.1% corundum, 4.5% quartz, and 0.5% K-feldspar. Overall, the fly ash from the power plant is significantly enriched in Al_2O_3 with an average of 51.9%, but poor in SiO_2, Fe_2O_3, CaO, MgO, Na_2O, P_2O_5, and As. Arsenic, TiO_2, Th, Al_2O_3, Bi, La, Ga, Ni, and V are high in mullite, and the magnetic matter is enriched in Fe_2O_3, CaO, MnO, TiO_2, Cs, Co, As, Cd, Ba, Ni, Sb, MgO, Zn, and V. The remaining elements are high in the glass fraction. The concentration of K_2O, Na_2O, P_2O_5, Nb, Cr, Ta, U, W, Rb, and Ni do not clearly vary with particle size, while SiO_2 and Hg decrease and the remaining elements clearly increase with decreasing particle size.

11/01079 Activated carbon prepared from PVDC by NaOH activation as electrode materials for high performance EDLCs with non-aqueous electrolyte

Xu, B. *et al. International Journal of Hydrogen Energy*, 2010, 35, (2), 632–637.

Mesoporous activated carbons with high surface area have been prepared from PVDC by NaOH activation for non-aqueous electric double layer capacitors (EDLCs). The BET surface area and pore volume of the carbon reach as high as 2675 $m^2\,g^{-1}$ and 1.683 $cm^3\,g^{-1}$, respectively. The pore size of the carbon distributes mainly in small mesopore of 2~4 nm, which is ideal for non-aqueous electrolyte EDLCs. The unique microstructure features, i.e. very high surface area and optimized pore size make the carbon present both a high capacitance of 155 F/g and outstanding rate capability in non-aqueous electrolytes. As the current density increases to 18 000 mA/g, it remains 109 F/g, an attractive value for EDLCs.

11/01080 Adsorption of complex phenolic compounds on active charcoal: breakthrough curves

Richard, D. *et al. Chemical Engineering Journal*, 2010, 158, (2), 213–219.

The transient adsorption of catechol from aqueous solution ($C^0 = 5\,kg/m^3$) on activated carbon in an upflow fixed-bed column at 293 K was studied. The critical time at which the early breakthrough of the maximum admissible concentration ($C_{crit} = 0.3\times10^{-3}\,kg/m^3$) occurs is deduced from a homogeneous surface diffusion model that accounts for adsorption equilibrium and mass-transfer kinetics. The mass-transfer coefficient is measured using a thin bed adsorption method and a correlation is proposed to account for its dependence with the flow rate. The sensitivity of the model for the prediction of the critical time to the different parameters is discussed and it is found to be mostly dependent on the mass-transfer coefficient *Kf* and the adsorbant mean particle diameter *dP*. In addition, the critical time has been proved to increase with the adsorption capacity q_{max}. The existence of an optimal flow of polluted effluent through the column to achieve the removal of the pollutant with the highest efficiency is observed.

11/01081 Adsorption of dibenzothiophenes on activated carbons with copper and iron deposited on their surfaces

Seredych, M. and Bandosz, T. J. *Fuel Processing Technology*, 2010, 91, (6), 693–701.

Three polymer-derived carbons with iron and different amounts of copper on the surface were investigated as adsorbents of dibenzothiophene (DBT) and 4,6-dimethyldibenzothiophene (DMDBT) from simulated diesel fuel. To characterize the initial and exhausted carbons nitrogen adsorption, elemental analysis, X-ray diffraction (XRD), scanning electron microscopy (SEM) and thermal analysis (TA) were applied. The selectivities for DBT and DMDBT were calculated with reference to naphthalene. In spite of the enhancement in selectivity for DBT and DMDBT removal caused by iron and copper species, the results indicate that the volume of micropores is the main factor governing the amount adsorbed. Oxidation of benzothiophenes is likely promoted by iron oxide and copper/copper oxide highly dispersed on the surface. The oxidation products are then selectively adsorbed on the surface of carbon in larger pores where metal species and heteroatoms are the active centres for adsorption of polar species.

11/01082 Application of wave propagation theory to adsorption breakthrough studies of toluene on activated carbon fibre beds

Zhang, X. *et al. Carbon*, 2010, 48, (8), 2317–2326.

Based on the wave propagation theory, a dynamics model that combines the non-linear equilibrium isotherm and the linear mass-transfer equation has been developed to predict the breakthrough behaviour of toluene adsorption in a fixed bed packed with activated carbon fibres. Experimental results showed that the constant-pattern wave model using the Langmuir isotherm equation could capture the dynamic behaviour of the adsorption column. Two important parameters, the half breakthrough time ($t_{1/2}$) and the volumetric mass-transfer coefficients ($k_G\alpha$) in the model were obtained from linear fitting of the model to experimental breakthrough data. The $k_G\alpha$ value was found to be insensitive to the initial concentration and increased with the increasing the superficial velocity. It was also observed that $t_{1/2}$ decreases with increasing the superficial velocity and the initial concentration, and increases with increasing the bed height. A sensitivity analysis showed that external mass-transfer had a much stronger influence on the breakthrough curve than internal mass-transfer, confirming that the overall mass-transfer for toluene adsorption onto activated carbon fibres in fixed bed is controlled by external mass-transfer.

11/01083 Development of mesoporous structure and high adsorption capacity of biomass-based activated carbon by phosphoric acid and zinc chloride activation

Liou, T.-H. *et al. Chemical Engineering Journal*, 2010, 158, (2), 129–142.

This paper reports on the preparation of activated carbon from two different types of agricultural biomass materials, sugar cane bagasse and sunflower seed hull, by phosphoric acid and zinc chloride activation. The experiments in this study vary the pre- and post-treatment procedures, the impregnation ratio of the activating agent, and the carbonization temperature. In recent years, the high surface area and high mesopore proportion of carbon have attracted a lot of attention for potential applications in the 'green' resources such as hydrogen energy storage and carbon dioxide capture. However, the traditional methods for fabricating activated carbon produce a mainly microporous structure. The experimental results show that the activated carbon produced by base-leaching has a mostly mesoporous structure, which effectively enhances its adsorption capacity. The carbon materials obtained from zinc chloride activation of both sugar cane bagasse and sunflower seed hull have mesopore volumes as high as 1.07 and 0.95 cm^3/g, and mesopore contents of 81.2 and 74.0%, respectively. The surface area and pore volume of carbon produced using zinc chloride activation were higher than that produced using phosphoric acid activation. The total activation process of bagasse and hull occurs in three reaction stages. This study also presents a corresponding pyrolysis mechanism that agrees well with the experimental results. The proposed method of preparing mesoporous activated carbon is not complicated, and is suitable to bulk production.

11/01084 Effect of Ca-substitution in $La_{1-x}Ca_xFeO_3$ perovskites on the catalytic activity for soot combustion

Jiménez, R. *et al. Fuel Processing Technology*, 2010, 91, (5), 546–549.

$La_{1-x}Ca_xFeO_3$ (x = 0.1, 0.2, 0.3 and 0.4) perovskites, prepared by the citrate method and characterized by AAS, XRD, TPR-H_2 and TPD-O_2, were assayed, and its catalytic activity evaluated for soot combustion, using carbon black as a model compound for soot. The catalytic activity was determined by non-isothermal thermogravimetric analysis. A significant enhancement of the catalytic activity was found by increasing the degree of La^{3+} substitution by Ca^{2+} in the perovskites, which coincided with an increase of the α-oxygen concentration and thus, a probable enrichment of the CB surface with these oxygenated species, at the start of the combustion.

11/01085 Evaluation of the radiological safety aspects of utilization of Turkish coal combustion fly ash in concrete production

Turhan, Ş. *et al. Fuel*, 2010, 89, (9), 2528–2535.

The aim of this study is to evaluate radiological safety aspects of the utilization of fly ash in concrete manufacturing in the construction industry. The specific activities of ^{226}Ra, ^{232}Th and ^{40}K in 155 concrete mixture samples incorporating 10, 20 and 30 wt% of fly ash collected from the 11 coal-fired thermal power plants were measured by means of gamma-ray spectrometry with HPGe detector. The results of the measurement were used to evaluate the radiological safety aspects of utilization of the fly ash as cement replacement in concrete by assessing the radium equivalent activity, the gamma index, the absorbed gamma dose rate and the corresponding annual effective dose due to the external exposure in indoor. The results of evaluation show that all concrete mixture samples are within the recommended safety limits except for concrete mixture samples incorporating 30 wt% fly ash of Kangal coal-fired thermal power plant.

11/01086 Influence of activated carbons on the kinetics and mechanisms of aromatic molecules ozonation

Merle, T. *et al. Catalysis Today*, 2010, 151, (1–2), 166–172.

Companies have been looking for new methods for treating toxic or refractory wastewaters; which can mainly be used prior to or after or in connexion with biological treatment processes. This paper compares conventional ozone oxidation with activated carbon (AC)-promoted ozone oxidation, which helps developing a mechanism involving HO radical. For a compound which is quite easy to oxidize, such as 2,4-dichlorophenol (2,4-DCP), conventional ozonation is efficient enough to remove the initial molecule. The mechanism involved mainly consists of an electrophilic attack on the aromatic ring, which is activated by the donor effect of the –OH group, then followed by a 1,3-dipolar cycloaddition (Criegee mechanism) that leads to aliphatic species, mainly carboxylic acids. Yet, the addition of AC, through the presence of the HO radical, enhances the removal of these species which are more refractory. For a refractory compound such as nitrobenzene (NB), with a deactivated aromatic ring (because of the attractive effect of $-NO_2$), conventional ozonation is inefficient. On the contrary, this molecule can be quite easily removed with AC-promoted oxidation and it is found that the mechanism (electrophilic attack followed by a 1,3-dipolar cycloaddition) is quite similar to the one corresponding to conventional ozonation, but with less selectivity. For both molecules, a mass balance has established that the by-products accounting for more than 75% of the remaining COD can be quantified. A significant part is composed of carboxylic acids (acetic, oxalic, etc.), which could afterwards be easily removed in an industrial wastewater treatment process followed by a final biological treatment step.

11/01087 Porous structure and sorption properties of nitrogen-containing activated carbon

Budaeva, A. D. and Zoltoev, E. V. *Fuel*, 2010, 89, (9), 2623–2627.

Nitrogen-containing activated carbon (NAC) derived from ammonium humates was produced and its porous structure (specific surface, pore volume) investigated. The NAC is mesoporous activated carbon with surface area of 557 m^2/g and containing 2.4 wt% of nitrogen. Sorption characteristics (sorption activity of iodine, methylene blue, benzene and metal ions Cu^{2+} and Pb^{2+}) of NAC are compared with activated charcoal and BAU-A.

11/01088 Sewage sludge conditioning with coal fly ash modified by sulfuric acid

Chen, C. *et al. Chemical Engineering Journal*, 2010, 158, (3), 616–622.

The activated sludge process to treat municipal and industrial wastewater produces huge amounts of excess sludge. Chemical conditioning has been employed widely to improve sludge mechanical dewatering, but the cost is high, thus it is very important to find cheap

and effective conditioners. This paper studied the improvement of sludge dewaterability with coal fly ash modified by sulfuric acid (MCFA). Through orthogonal experiments with specific resistance to filtration (SRF) as the target index, acid concentration and soaking time were verified to be the important influencing parameters in coal fly ash modification. The optimal modification conditions were: acid concentration, 4 mol l^{-1}; ratio of acid to coal fly ash, 5:1 ml g^{-1}; soaking time, 3 h. After modification the specific surface area of coal fly ash increased from 2.810 to 3.376 $m^2 g^{-1}$. The dewaterability and the settleability of the conditioned sludge were investigated with vacuum filtrating dewatering tests, centrifugal dewatering tests and settling experiments. The results showed that SRF of the sludge significantly decreased with coal fly ash addition, and the MCFA showed much stronger conditioning capacity than the raw coal fly ash. Under a MCFA dosage of 273%, the SRF of the sludge decreased from 1.86×10^{13} to 4.23×10^{11} m kg^{-1}, and the filter cake moisture decreased from 86.90% to 56.52%. The sludge conditioning mechanisms with MCFA mainly included improving floc formation through charge neutralization and adsorption bridging and providing the water transmitting passages by skeleton builder.

11/01089 Tar removal from biomass pyrolysis gas in two-step function of decomposition and adsorption
Phuphuakrat, T. *et al. Applied Energy*, 2010, 87, (7), 2203–2211.
Tar content in syngas pyrolysis is a serious problem for fuel gas utilization in downstream applications. This paper investigated tar removal, by the two-step function of decomposition and adsorption, from the pyrolysis gas. The temperature of the tar decomposition process was fixed at 800 °C both with and without steam, with air as the reforming agent. Both steam and air had a strong influence on the tar decomposition reaction. The reduction of the gravimetric tar mass was 78% in the case of the thermal cracking, whereas, it was in the range of 77–92% in the case of the steam and air forming. Under conditions of tar decomposition, the gravimetric tar mass reduced, while the yield of the combustible gaseous components in the syngas increased. Synchronously, the amount of light tars increased. This should be eliminated later by fixed-bed adsorption. Three adsorbents (activated carbon, wood chip, and synthetic porous cordierite) were selected to evaluate the adsorption performance of light tars, especially of condensable tar. Activated carbon showed the best adsorption performance among all light tars, in view of the adsorption capacity and breakthrough time. On the other hand, activated carbon decreased the efficiency of the system due to its high adsorption performance with non-condensable tar, which is a combustible substance in syngas. Synthetic porous cordierite showed very low adsorption performance with almost all light tars, whereas, wood chip showed a high adsorption performance with condensable tar and low adsorption performance with non-condensable tar. When compared with other adsorbents, wood chip showed a prominent adsorption selectivity that was suitable for practical use, by minimizing the condensable tar without decreasing the efficiency of the system.

11/01090 The effect of water uptake in ultramicropores on the adsorption of water vapour in activated carbon
Lodewyckx, P. *Carbon*, 2010, 48, (9), 2549–2553.
The kinetics of the adsorption of water vapour on activated carbon were investigated. The experimental data show two adsorption mechanisms: a rather fast one and a very slow one. The first one has been modelled previously. The latter is found to be the result of water penetrating into ultramicropores with dimensions comparable to that of the water molecules. The slow kinetics could be explained by the formation of nanochains, not unlike the mechanism that has been demonstrated for water adsorption through nanogates in nanohorns.

11/01091 Thermal performance of a carbon fiber composite material heat sink in an FC-72 thermosyphon
Gandikota, V. *et al. Experimental Thermal and Fluid Science*, 2010, 34, (5), 554–561.
This study analyses the use of a carbon fibre epoxy heat sink for evaporator surface enhancement in a FC-72 thermosyphon. The pin-fin heat sink features 945 small-cross-section (1.27 mm by 0.965 mm) fins fabricated with an integral base plate. These fins have a high thermal conductivity (500 W/m K) along the length of the fin. The influence of heat load, thermosyphon fill volume, and condenser operating temperature on the overall thermal performance is examined. The results of this experiment provide significant insight into the possible implementation and potential benefits of carbon-fibre heat sink technology in two-phase flow leading to significant improvements in thermal management strategies for advanced electronics.

05 NUCLEAR FUELS

Scientific, technical

11/01092 Activation analysis and waste management of China ITER helium cooled solid breeder test blanket module
Han, J. R. *et al. Fusion Engineering and Design*, 2010, 85, (5), 761–765.
Activation characteristics have been assessed for the ITER China helium cooled solid breeder (CH-HCSB) 3×6 test blanket module (TBM). Taking a representative irradiation scenario, the activation calculations were performed by FISPACT code. Neutron fluxes distributions in the TBM were provided by a preceding MCNP calculation. These fluxes were passed to FISPACT for the activation calculation. The main activation parameters of the HCSB-TBM were calculated and discussed, such as activity, afterheat and contact dose rate. Meanwhile, the dominant radioactivity nuclides and reaction channel pathways have been identified. According to the Safety and Environmental Assessment of Fusion Power waste management strategy, the activated materials can be re-used following the remote handling recycling options. The results will provide useful indications for further optimization design and waste management of the TBM.

11/01093 An integrated translation of design data of a nuclear power plant from a specification-driven plant design system to neutral model data
Mun, D. and Yang, J. *Annals of Nuclear Energy*, 2010, 37, (3), 389–397.
How to efficiently integrate and manage lifecycle data of a nuclear power plant has gradually become an important object of study. Because plants usually have a very long period of operation and maintenance, the plant design data need to be presented in a computer-interpretable form and to be independent of any commercial systems. The conversion of plant design data from various design systems into neutral model data is therefore an important technology for the effective operation and maintenance of plants. In this study, a neutral model for the efficient integration of plant design data is chosen from among the currently available options and extended in order to cover the information model requirements of nuclear power plants in Korea. After the mapping of the neutral model and the data model of a specification-driven plant design system, a plant data translator is also implemented in accordance with the schema mapping results.

11/01094 Criticality and burn up evolutions of the fixed bed nuclear reactor with alternative fuels
Şahin, S. *et al. Energy Conversion and Management*, 2010, 51, (9), 1781–1787.
Time evolution of criticality and burn-up grades of the fixed bed nuclear reactor (FBNR) are investigated for alternative fuels. These are: (1) low enriched uranium, (2) weapon grade plutonium, (3) reactor grade plutonium and (4) minor actinides in the spent fuel of light water reactors (LWRs). The criticality calculations are conducted with SCALE 5.1 using S_8-P_3 approximation in 238 neutron energy groups with 90 groups in thermal energy region. The main results of the study can be summarized as follows: (1) low enriched uranium (UO_2): FBNR with an enrichment grade of 9% and 19% will start with k_{eff} = 1.2744 and k_{eff} = 1.36 and can operate ~8 and >15 years with the same fuel charge, where criticality drops to k_{eff} = 1.06 and a burn-up grade of 54 000 and >110 000 MW.D/t can be attained. (2) Weapon grade plutonium: such a high-quality nuclear fuel suggests to be mixed with thorium. Second series of criticality calculations are conducted with fuel compositions made of thoria (ThO_2) and weapon grade PuO_2, where PuO_2 component has been varied from 1% to 100%. Criticality with $k_{eff} > 1.0$ is achieved by ~2.5% PuO_2. At 4% PuO_2, the reactor criticality will become satisfactory (k_{eff} = 1.1121), rapidly increasing with more PuO_2. A reasonable mixture will by around 20% PuO_2 and 80% ThO_2 with a k_{eff} = 1.2864. This mixed fuel would allow full power reactor operation for >20 years and burn-up grade can reach 136 000 MW.D/t. (3) Reactor grade plutonium: third series of criticality calculations are conducted with fuel compositions made of thoria and reactor grade PuO_2, where PuO_2 is varied from 1% to 100%. Reactor becomes critical by ~8% PuO_2 content. One can achieve k_{eff} = 1.2670 by 35% PuO_2 and would allow full power reactor operation also for >20 years and burn-up grade can reach 123 000 MW.D/t. (4) Minor actinides in the spent fuel of LWRs: fourth series of criticality calculations are conducted with fuel compositions made of thoria and MAO_2, where MAO_2 is varied from 1% to 100%. Reactor becomes critical by ~17% MAO_2 content. Reasonably high reactor criticality (k_{eff} = 1.2673) is achieved by 50% MAO_2 for a reactor operation time

of 15 years with a burn up of 86 000 MW.D/t without fuel change. On that way, the hazardous nuclear waste product can be transmuted as well as utilized as fuel.

11/01095 Criticality aspects of nuclear power reactor cores in the case of emerging nuclear fuels

Nicolaou, G. *Annals of Nuclear Energy*, 2010, 37, (2), 285–288.

Reactor cores of pressurized water reactor (PWR) and liquid metal fast-breeder reactor (LMFBR), loaded with different commercial and emerging nuclear fuels, have been simulated and compared at beginning of irradiation BOI with respect to criticality with and without chemical shim, control rods and sodium. The different cases considered, within each of the reactor types, are grouped together according to their fissile content, when compared on the basis of the neutron multiplication factor (k_{eff}). For both PWR and LMFBR reactor types, the reactivity worths of the control rods do not change significantly when replacing commercial fuels by emerging ones. In the case of the LMFBR, the Na void reactivity effects are small and comparable using either emerging or commercial fuels. Hence, operation and control of the core at beginning of irradiation are similar for emerging or commercial fuels.

11/01096 Evolution of nuclear fission reactors: third generation and beyond

Marques, J. G. *Energy Conversion and Management*, 2010, 51, (9), 1774–1780.

Nuclear energy is attracting new interest around the world as countries look for low-carbon alternatives to fossil fuels to increase the diversity of their sources of energy and improve security of supply. Nuclear fission reactors provided approximately one-sixth of the world's electricity needs in recent years. The vast majority of these reactors were built in the 1970s and 1980s. They are thus considered second generation systems, as they are based on experience gained with the first generation or prototypes built in the 1950s and early 1960s. Third generation reactors, developed in the 1990s, are already a reality and will dominate the market in the coming decades. A significant research effort is underway on systems of the fourth generation. Better economics, improved use of natural resources, less production of radioactive waste, competitive production of hydrogen, and increased resistance to proliferation are within reach with these new systems. A review will be done on the most important features of third and fourth generation systems, together with a brief overview of the R&D challenges to be met.

11/01097 Exact nuclear data uncertainty propagation for fusion neutronics calculations

Rochman, D. *et al. Fusion Engineering and Design*, 2010, 85, (5), 669–682.

An exact method (now called 'total Monte Carlo') was previously published to propagate uncertainties of fundamental nuclear physics experiments, models and parameters to different types of criticality-safety benchmarks. This paper now shows that such exact uncertainty calculations are directly relevant to the optimal and safe design of fusion reactors by applying this methodology to a series of fusion shielding benchmarks, namely those connected to the Oktavian, Fusion Neutronics Source and LLNL Pulsed Sphere experiments. Uncertainties on neutron and gamma leakage fluxes for 13 shielding benchmarks are obtained, in the mass range from ^{nat}Mg to ^{nat}W. Uncertainties for cross-sections, angular distributions, single- and double-differential emission spectra, and gamma-ray production cross-sections are considered in this uncertainty propagation scheme.

11/01098 Experimental investigation on the flow instability behavior of a multi-channel boiling natural circulation loop at low-pressures

Jain, V. *et al. Experimental Thermal and Fluid Science*, 2010, 34, (6), 776–787.

Natural circulation as a mode of heat removal is being considered as a prominent passive feature in the innovative nuclear reactor designs, particularly in boiling-water-reactors, due to its simplicity and economy. However, boiling natural circulation system poses many challenges to designer due to occurrence of various kinds of instabilities such as excursive instability, density wave oscillations, flow pattern transition instability, geysering and metastable states in parallel channels. This problem assumes greater significance particularly at low-pressures, i.e. during startup, where there is great difference in the properties of two phases. In light of this, a parallel channel loop has been designed and installed that has a geometrical resemblance to the pressure-tube-type boiling-water-reactor, to investigate into the behaviour of boiling natural circulation. The loop comprises of four identical parallel channels connected between two common plenums i.e. steam drum and header. The recirculation path is provided by a single downcomer connected between steam drum and header. Experiments have been conducted over a wide range of power and pressures (1–10 bar). Two distinct unstable zones are observed with respect to power i.e. corresponding to low power (Type-I) and high power (Type-II) with a stable zone at intermediate powers. The nature of oscillations in terms of their amplitude and frequency and their evolution for Type-I and Type-II instabilities are studied with respect to the effect of heater power and pressure. This paper discusses the evolution of unstable and stable behaviour along with the nature of flow oscillation in the channels and the effect of pressure on it.

11/01099 Implications of NSTX lithium results for magnetic fusion research

Ono, M. *et al. Fusion Engineering and Design*, 2010, 85, (6), 882–889.

Lithium wall coating techniques have been experimentally explored on National Spherical Torus Experiment (NSTX) for the past 5 years. The lithium experimentation on NSTX started with a few milligrams of lithium injected into the plasma as pellets and it has evolved to a lithium evaporation system which can evaporate up to ~100 g of lithium onto the lower divertor plates between lithium re-loadings. The unique feature of the lithium research program on NSTX is that it can investigate the effects of lithium in H-mode divertor plasmas. This lithium evaporation system thus far has produced many intriguing and potentially important results; the latest of these are summarized in a companion paper. This paper suggests possible implications and applications of the NSTX lithium results on the magnetic fusion research which include electron and global energy confinement improvements, MHD stability enhancement at high beta, edge localized mode (ELM) control, H-mode power threshold reduction, improvements in radio frequency heating and non-inductive plasma start-up performance, innovative divertor solutions and improved operational efficiency.

11/01100 Indexing of plasma waveforms for accelerating search and retrieval of their subsequences

Hochin, T. *et al. Fusion Engineering and Design*, 2010, 85, (5), 649–654.

This paper proposes an indexing method of plasma waveforms for accelerating search and retrieval of their subsequences. The proposed method divides a waveform into fine-grained segments. The similar segments are grouped into a segment group. A multi-dimensional index is used for quick retrieval. Grouping segments could save the amount of the index. In the retrieval, a sequence of segments, which is called a section, is used as a unit in matching subsequences. Overlapping sections could overcome the shift errors of subsequences, and results in good retrieval correctness.

11/01101 Inter-comparison of JEF-2.2 and JEFF-3.1 evaluated nuclear data through Monte Carlo analysis of VVER-1000 MOX Core Computational Benchmark

Thilagam, L. *et al. Annals of Nuclear Energy*, 2010, 37, (2), 144–165.

Nuclear data is evaluated and modified on a continuous basis by different nuclear data centres and laboratories worldwide. Use of different sets of cross-section data in the analysis of a benchmark problem is a source of strong feedback for further improvements in data by mutual comparison of results. These comparisons also help to find out the best evaluated cross-section data released. This study compares JEF-2.2 and JEFF-3.1 evaluated nuclear data through the Monte Carlo simulation of 'VVER-1000 MOX Core Computational Benchmark'. It deals with the calculation and inter-comparison of reactor parameters such as multiplication factors, cell average and assembly average fission reaction rate distributions estimated for various reactor state descriptions specified in the benchmark. Point-wise cross-section libraries processed from the JEF-2.2 and JEFF-3.1 evaluated data are used in the analysis. Concerning the multiplication factors and fission rate distributions, considerable differences are observed between the two libraries. While performing the MCNP calculations with JEFF-3.1 data, it is observed that the deviations of effective neutron multiplication factors (k_{eff}) from those of benchmark standard MCU results are lower by about 0.100% for the most of the states than those computed using JEF-2.2. Fission rate distributions using JEFF-3.1 data are also found to have significant deviations up to ±9.2% compared to calculations with its earlier version JEF-2.2 data. Some interesting trends on the used nuclear data are identified from the discrepancies of the individual results. The cause for considerable changes in the calculated parameters are analysed and an attempt to correlate the observed changes to the cross-sections of the relevant nuclides in the two nuclear data evaluations is made.

11/01102 Parameter study of the LIFE engine nuclear design

Kramer, K. J. *et al. Energy Conversion and Management*, 2010, 51, (9), 1744–1750.

LLNL is developing the nuclear fusion based laser inertial fusion energy (LIFE) power plant concept. The baseline design uses a depleted uranium (DU) fission fuel blanket with a flowing molten salt coolant (flibe) that also breeds the tritium needed to sustain the fusion energy source. Indirect drive targets, similar to those that will be demonstrated on the national ignition facility (NIF), are ignited at

about 13 Hz providing a 500 MW fusion source. The DU is in the form of a uranium oxycarbide kernel in modified TRISO-like fuel particles distributed in a carbon matrix forming 2-cm-diameter pebbles. The thermal power is held at 2000 MW by continuously varying the ^{6}Li enrichment in the coolants. There are many options to be considered in the engine design including target yield, U-to-C ratio in the fuel, fission blanket thickness, etc. Here the authors report results of design variations and compare them in terms of various figures of merit such as time to reach a desired burnup, full-power years of operation, time and maximum burnup at power ramp-down and the overall balance of plant utilization.

Economics, policy, supplies, forecasts

11/01103 A 'must-go path' scenario for sustainable development and the role of nuclear energy in the 21st century

Jeong, H.-Y. *et al. Energy Policy*, 2010, 38, (4), 1962–1968.

An increase in the world population has accelerated the consumption of fossil fuels and deepened the pollution of global environment. As a result of these human activities, it is now difficult to clearly guarantee the sustainable future of humankind. An intuitional 'must-go path' scenario for the sustainable development of human civilization is proposed by extrapolating the human historical data over 30 years between 1970 and 2000. One of the most important parameters in order to realize the 'must-go path' scenario is the sustainability of energy without further pollution. In some countries an expanded use of nuclear energy is advantageous to increase sustainability, but fast reactor technology and closed fuel cycle have to be introduced to make it sustainable. In other countries, the development of cost-effective renewable energy, and the clean use of coal and oil are urgently needed to reduce pollution. The effect of fast nuclear reactor technology on sustainability as an option for near-term energy source is detailed in this paper. More cooperation between countries and worldwide collaboration coordinated by international organizations are essential to make the 'must-go path' scenario real in the upcoming 20 or 30 years.

11/01104 Computational analysis of neutronic parameters for TRIGA Mark-II research reactor using evaluated nuclear data libraries

Uddin, M. N. *et al. Annals of Nuclear Energy*, 2010, 37, (3), 302–309.

The aim of this study is to analyse the neutronic parameters of TRIGA Mark-II research reactor using the chain of NJOY-WIMS-CITATION computer codes based on evaluated nuclear data libraries CENDL-2.2 and JEFF-3.1.1. The nuclear data processing code NJOY99.0 has been employed to generate the 69 group WIMS library for the isotopes of TRIGA core. The cell code WIMSD-5B was used to generate the cross sections in CITATION format and then three-dimensional diffusion code CITTATION was used to calculate the neutronic parameters of the TRIGA Mark-II research reactor. All the analyses were performed using the seven-group macroscopic cross section library. The CITATION test-runs using different cross section sets based on different models applied in WIMS calculations have shown a strong influence of those models on the final integral parameters. Some of the cells were specially treated with PRIZE options available in WIMSD-5B to take into account the fine structure of the flux gradient in the fuel-reflector interface region. It was observed that two basic parameters, the effective multiplication factor, k_{eff} and the thermal neutron flux, were in good agreement among the calculated results with each other as well as the measured values. The maximum power densities at the hot spot were 1.0446E02 W/cc and 1.0426E02 W/cc for the libraries CENDL-2.2 and JEFF-3.1.1 respectively. The calculated total peaking factors 5.793 and 5.745 were compared to the original SAR value of 5.6325 as well as MCNP result. Consequently, this analysis will be helpful to enhance the neutronic calculations and also be used for the further thermal–hydraulics study of the TRIGA core.

11/01105 From conventional nuclear power reactors to accelerator-driven systems

Yasin, Z. and Shahzad, M. I. *Annals of Nuclear Energy*, 2010, 37, (2), 87–92.

Spent fuel from nuclear power plants has become one of the key issues in the use of nuclear energy. Some problems attributed to the conventional nuclear power reactors along with their solutions and a historical transition from nuclear power reactors to accelerator-driven systems are briefly reviewed in the present work. It is argued that accelerator-driven systems (ADS), for transmutation of nuclear waste and energy production, are good alternatives to the conventional nuclear power plants. Important differences between the conventional nuclear reactors and the ADS along with the ADS physics are discussed. The ADS is considered to be relatively safe as compared to the other nuclear power reactors commonly in use.

11/01106 Hybrid reactors: nuclear breeding or energy production?

Piera, M. *et al. Energy Conversion and Management*, 2010, 51, (9), 1758–1763.

After reviewing the long-standing tradition on hybrid research, an assessment model is presented in order to characterize the hybrid performance under different objectives. In hybrids, neutron multiplication in the subcritical blanket plays a major role, not only for energy production and nuclear breeding, but also for tritium breeding, which is fundamental requirement in fusion–fission hybrids. All three objectives are better achieved with high values of the neutron multiplication factor with the obvious and fundamental limitation that it cannot reach criticality under any event, particularly, in the case of a loss of coolant accident. This limitation will be very important in the selection of the coolant. Some general considerations will be proposed, as guidelines for assessing the hybrid potential in a given scenario. Those guidelines point out that hybrids can be of great interest for the future of nuclear energy in a framework of sustainable development, because they can contribute to the efficient exploitation of nuclear fuels, with very high safety features. Additionally, a proposal is presented on a blanket specially suited for fusion–fission hybrids, although this reactor concept is still under review, and new work is needed for identifying the most suitable blanket composition, which can vary depending on the main objective of the hybrid.

11/01107 Projections of US GHG reductions from nuclear power new capacity based on historic levels of investment

Besmann, T. M. *Energy Policy*, 2010, 38, (5), 2431–2437.

Historical rates of capital investment in nuclear plant construction were used as a guide to estimate the potential rate of future capacity introduction. The total linear rate of capital expenditure over the entire period of historical construction from 1964 to 1990 was determined to equal $11.5 billion/year, and that for the period of peak construction from 1973 to 1985 was computed as $17.9 billion/year, all in 2004 dollars. These values were used with a variety of current capital cost estimates for nuclear construction to obtain several scenarios for possible future nuclear capacity additions. These values were used to obtain the effect of projected nuclear generating capacity on greenhouse gas emissions assuming nuclear would directly replace coal-fired generation. It was concluded that actual reductions in emissions would not be experienced until 2038, yet growth in emissions from electrical production would be slowed through that period. Due to the significant time to introduce large-scale changes in the utility sector, nuclear energy cannot have a dramatic short-term effect on emissions. Nuclear power, however, can have a major positive longer term impact, particularly under more favourable cost and investment conditions.

11/01108 The research reactor radiation emergency countermeasure system in Korea

Kim, H. R. *et al. Annals of Nuclear Energy*, 2010, 37, (2), 175–179.

A disaster prevention system was established for a radiation emergency from an operation of a research reactor with a thermal power of 30 MW_{th} in Korea. A national radiation disaster countermeasure organization was set up to cope with the radiation emergency classified into three cases whose effective doses were more than 1 mSv/h inside the nuclear facility, inside the site boundary and outside the site boundary. Its role consists of the proclamation and consequent withdrawal of a disaster, a general assessment, an emergency medical service, a field control, radiation protection, resident protection implement, an accident analysis, a security plan, a radiation environmental investigation plan and probe, a radiation environmental effect assessment, and others. The emergency planning zone was settled to be within a radius of 800 m, the average distance between the site boundary and the centre of a research reactor in operation, as a quick and effective early countermeasure from the result of the radiation environmental effect assessment. The environmental probing zone was chosen to extend to a radius of 2 km from a research reactor according to the moving path of the radioactive cloud so that a densely populated area could be considered and would be extended to 10 km according to the radiation level of the research reactor and atmospheric diffusion. Practically, the environmental probing is implemented at 22 points inside the site and eight points outside the site considering the geography, population and the wind direction. The gamma radiation dose and atmospheric radioactivity are analysed during an effluence, and the radioactivity of a ground surface deposit and an environmental sample are analysed after an effluence. The environmental laboratory covers the analysis of the gamma radioisotopes, tritium, strontium, uranium, gross alpha and beta. It is estimated that the habitability can be recovered when the radiation dose rate is less than 1 mSv/h inside the site and around the environmental laboratory with the no sign of an

effluence of the radioactive material. As a conclusion, it is thought that this emergency countermeasure system is effective in a real radiation emergency situation.

11/01109 Thermoeconomic optimization of a hybrid pressurized water reactor (PWR) power plant coupled to a multi effect distillation desalination system with thermo-vapour compressor (MED-TVC)
Ansari, K. *et al. Energy*, 2010, 35, (5), 1981–1996.
Thermoeconomic optimization of a typical 1000 MW pressurized water reactor (PWR) nuclear power plant coupled to a multi-effect distillation (MED) desalination system with thermo-vapour compressor (TVC) is performed. A thermodynamic modelling based on the energy and exergy analysis is performed while economic modelling is developed based on the total revenue requirement (TRR) method. The objective function based on the thermoeconomic analysis is obtained. The proposed cogeneration plant, for simultaneous production of power and fresh water, including 16 decision variables is proposed for thermoeconomic optimization in which the goal is minimizing the cost of system product (including the cost of generated electricity and fresh water). The optimization process is performed using a stochastic/deterministic optimization approach as a genetic algorithm. It is found that thermoeconomic optimization aims at reduction of sub-components total costs by reducing either the cost of inefficiency or the cost of owning the components, whichever is dominant. For some components such as evaporators, the improvement is obtained by reducing the owning cost of the sub-system at the cost of reduction of the thermodynamic efficiency. For components like as TVC + de-superheater, improvement is achieved by increasing the thermodynamic efficiency or decreasing the inefficiency cost.

06 ELECTRICAL POWER SUPPLY AND UTILIZATION

Scientific, technical

11/01110 A new fuzzy adaptive particle swarm optimization for daily Volt/Var control in distribution networks considering distributed generators
Niknam, T. *et al. Applied Energy*, 2010, 87, (6), 1919–1928.
This paper presents a novel approach for daily Volt/Var control in distribution systems using distributed generation (DG) units. The impact of DG units on Volt/Var control is significant in a distribution network with radial configuration and small X/R ratio. In this paper, a price-based approach is adopted to determine the optimum active and reactive power dispatch for the DG units, the reactive power contribution of the capacitor banks, and the tap settings of the transformers in a day in advance. A fuzzy adaptive particle swarm optimization (FAPSO) method is used to solve the daily Volt/Var control which is a non-linear mixed-integer problem. A mathematical expression of the proposed method and its effectiveness using simulation results are provided.

11/01111 A software application for energy flow simulation of a grid connected photovoltaic system
Hamad, A. A. *et al. Energy Conversion and Management*, 2010, 51, (8), 1684–1689.
A computer software application was developed to simulate hourly energy flow of a grid connected photovoltaic system. This software application enables conducting an operational evaluation of a studied photovoltaic system in terms of energy exchange with the electrical grid. The system model consists of a photovoltaic array, a converter and an optional generic energy storage component that supports scheduled charging/discharging. In addition to system design parameters, the software uses hourly solar data and hourly load data to determine the amount of energy exchanged with electrical grid for each hour of the simulated year. The resulting information is useful in assessing the impact of the system on demand for electrical energy of a building that uses it. The software also aggregates these hourly results in daily, monthly and full year sums. The software finds the financial benefit of the system as the difference in grid electrical energy cost between two simultaneously considered cases. One is with load supplied only by the electrical grid, while the other is with the photovoltaic system present and contributing energy. The software supports the energy pricing scheme used in Jordan for domestic consumers, which is based on slices of monthly consumption. By projecting the yearly financial results on the system lifetime, the application weighs the financial benefit resulting from using the system against its cost, thus facilitating an economical evaluation.

11/01112 Analysis of low temperature solar thermal electric generation using regenerative organic Rankine cycle
Pei, P. *et al. Applied Thermal Engineering*, 2010, 30, (8–9), 998–1004.
The innovative configuration of low temperature solar thermal electric generation with regenerative organic Rankine cycle (ORC) is designed, mainly consisting of small concentration ratio compound parabolic concentrators (CPC) and the regenerative ORC. Advantages of the innovative configuration such as effectively reducing heat transfer irreversibility and permitting the use of thermal storage with phase change materials (PCMs) are outlined. The numerical simulation of the heat transfer and power conversion processes are carried out based on distributed parameters. The effects of regenerative cycle on the collector, ORC, and overall electricity efficiency are then analysed. The results indicate that the regenerative cycle has positive effects on the ORC efficiency but negative ones on the collector efficiency due to increment of the average working temperature of the first-stage collectors. Thus, it is necessary to evaluate the overall electricity efficiency when regenerative cycle is adopted. Further investigation shows that there are maximum efficiencies for both the ORC and the system electric generation on conditions of constant irradiance, evaporation temperature, and environment temperature. And the regenerative temperature at which the system electricity efficiency reaches its maximum is smaller than that at which the ORC efficiency reaches its maximum by 12–21 °C. Thus, the regenerative cycle optimization of the solar thermal electric generation differs from that of a solo ORC. The system electricity efficiency with regenerative ORC is about 8.6% for irradiance 750 W/m^2 and is relatively higher than that without the regenerative cycle by 4.9%.

11/01113 Bio-catalyzed electrochemical treatment of real field dairy wastewater with simultaneous power generation
Mohan, S. V. *et al. Biochemical Engineering Journal*, 2010, 51, (1–2), 32–39.
Biologically catalysed electrochemical treatment of real field dairy wastewater in association with power generation was studied in single chamber non-catalysed microbial fuel cell (MFC, open-air cathode). The performance was evaluated at four organic loads employing anaerobic mixed consortia as anodic biocatalyst. Experimental data illustrated the integrated function of MFC to harness bioelectricity from the treatment of dairy wastewater. Along with good substrate degradation [chemical oxygen demand (COD), 95.49%], MFC also documented good removal of proteins (78.07%), carbohydrates (91.98%) and turbidity (99.02%). A steady increase in MFC performance was observed with increase in substrate load. Maximum volumetric power production (1.10 W/m^3; 308 mV; 1.78 mA) was observed at 4.44 kg COD/m^3. MFC performance as power generator was characterized based on polarization behaviour, cell potentials, cyclic voltammetric analysis and sustainable power estimation. In view of inherent advantages of the process, if optimized and understood well, this integrated approach can be a good replacement for the conventional biological and electrochemical wastewater treatment processes.

11/01114 Decentralized electricity system sizing and placement in distribution networks
Niemi, R. and Lund, P. D. *Applied Energy*, 2010, 87, (6), 1865–1869.
A rapid method for sizing and placing of distributed electricity generation (DES) systems in an electric transmission network in respect to voltage has been developed and successfully validated. The new tool presented is in particularly useful for avoiding overvoltage situations, which are critical for the whole electricity system. The results show that DES placement closer to the transformer side is always more beneficial in terms of voltage than at the end of the line. Depending on the size of the DES unit, both up and downstream flow of power may occur. The method can be used for investigating a range of different placement and sizing configurations.

11/01115 Effects of organic loading rates on the continuous electricity generation from fermented wastewater using a single-chamber microbial fuel cell
Nam, J.-Y. *et al. Bioresource Technology*, 2010, 101, (S1), S33–S37.
Novel coupling of single-chamber microbial fuel cells (MFCs) with granular activated carbon anodes were constructed, and their ability to produce electricity from fermented wastewater operating in continuous mode was investigated. MFCs treating real fermented wastewater can generate a power density of approximately 1884 mW/m^3, which is equivalent to approximately 51.5% of that obtained from the MFCs (3664 mW/m^3) using acetate at the same organic loading rate (OLR) of 1.92 g/L d. As the OLR was increased in a stepwise fashion, power

density increased to 2981 mW/m^3 at an OLR of 3.84 g/L d. The corresponding energy production was 268 kJ/m^3 d. The decrease in the power density was mainly due to the higher internal resistance resulted from complex substrate. Based on the electrode characteristics, it was verified that colloidal particulates and complex organics in the real fermented wastewater not only lowered power density but also played a role as rate-limiting factors in the continuous generation of electricity.

11/01116 Exergetic analysis of an innovative small scale combined cycle cogeneration system

Badami, M. and Mura, M. *Energy*, 2010, 35, (6), 2535–2543.

The purpose of this paper has been to carry out an exergetic analysis of an innovative natural gas (NG) combined cycle cogeneration system (150-kW$_e$, 192-kW$_t$). The combined cycle is composed of a reciprocating internal combustion engine (ICE), which is used as the topping cycle, and a water Rankine cycle (RC), which operates on the exhaust gases from the ICE, as the bottoming cycle. A steady-state model has been developed in order to identify and to quantify the exergetic irreversibilities of each component of the system and of the whole plant. Furthermore, a part-load exergy analysis, which shows the exergy performance in the operating field of the plant, has been carried out; finally, a sensitivity analysis pertaining to some performance parameters is presented.

11/01117 Experimental evaluation of envelope tracking techniques for voltage disturbances

Marei, M. I. *et al. Electric Power Systems Research*, 2010, 80, (3), 339–344.

In this paper a digital signal processor (DSP)-based real-time voltage envelope tracking system is developed and examined. The adaptive linear neuron (ADALINE) and the recursive least square (RLS) algorithms are adopted for envelope tracking. The proposed ADALINE and RLS algorithms give accurate results even under rapid dynamic changes. The paper investigates the effects of different parameters on the performance of the ADALINE algorithm and that of the RLS algorithm. The experimental system is centred around a Texas Instrument 16 bit fixed-point arithmetic (TMS320LF2407A) evaluation board. Both the ADALINE and the RLS tracking algorithms are developed using the DSP-assembly language. A simple voltage flicker generator is implemented to produce various voltage disturbances. Extensive tests of the proposed envelope tracking algorithms are conducted to evaluate their dynamic performance.

11/01118 Maintaining a neutral water balance in a 450 MW$_e$ NGCC-CCS power system with post-combustion carbon dioxide capture aimed at offshore operation

Kvamsdal, H. M. *et al. International Journal of Greenhouse Gas Control*, 2010, 4, (4), 613–622.

A post-combustion CO_2 capture process intended for offshore operations has been designed and optimized for integration with a natural gas-fired power plant on board a floating structure developed by the Norway-based company Sevan Marine ASA – designated Sevan GTW (gas-to-wire). The concept is constrained by the structure of the floater carrying a SIEMENS modular power system rated at 450 MW$_e$, with a capture rate of 90% and CO_2 compression (1.47 Mtpa) for pipeline pressure at 12 MPa. A net efficiency of 45% (based on a lower heating value) is estimated for the system with CO_2 capture, thus suggesting that the post-combustion CO_2 capture system is accountable for a fuel penalty of nine percentage points. The rationale behind the technology selection is the urgency of replacing the dispersed aero-derivative gas turbines which power the offshore oil and gas production units in Norwegian waters with near-zero emission power. As (inherently) fresh water usually constitutes a limiting factor in sea operations, efforts are made to obtain a neutral water balance to obtain an optimal design. This is primarily achieved by controlling the cleaned flue gas temperature at the top of the absorber column.

11/01119 Micro-combined cooling, heating and power systems hybrid electric-thermal load following operation

Mago, P. J. *et al. Applied Thermal Engineering*, 2010, 30, (8–9), 800–806.

Micro-combined cooling, heating and power (mCCHP), typically designated as less than 30 kW electric, is a technology that generates electricity at or near the place where it is used. The waste heat from the electricity generation can be used for space cooling, space heating, or water heating. The operation of mCCHP systems, while obviously dependent upon the seasonal atmospheric conditions, which determine the building thermal and power demand, is ultimately controlled by the operation strategy. Two of the most common operation strategies are to run the prime mover in accordance to either electrical or thermal demand. In this study, a mCCHP system operating following a hybrid electric-thermal load (FHL) is proposed and investigated. This operation strategy is evaluated and compared with mCCHP systems operating following the electric load (FEL) and operating following the thermal load (FTL). This evaluation and comparison is based on site energy consumption (SEC), primary energy consumption (PEC), operational cost, and carbon dioxide emission reduction (CDE). Results show that mCCHP systems operated following the hybrid electric-thermal load have better performance than mCCHP-FEL and mCCHP-FTL. mCCHP-FHL showed higher reductions of PEC, operational cost, and carbon dioxide emissions than the ones obtained for the other two operation strategies for the evaluated case.

11/01120 Prospects for large scale electricity storage in Denmark

Ekman, C. K. and Jensen, S. H. *Energy Conversion and Management*, 2010, 51, (6), 1140–1147.

In a future power systems with additional wind power capacity there will be an increased need for large-scale power management as well as reliable balancing and reserve capabilities. Different technologies for large-scale electricity storage provide solutions to the different challenges arising with high wind power penetration. This paper presents a review of the electricity storage technologies relevant for large power systems. The paper also presents an estimation of the economic feasibility of electricity storage using the west Danish power market area as a case.

11/01121 Thermodynamic analysis of a tri-generation system based on micro-gas turbine with a steam ejector refrigeration system

Ameri, M. *et al. Energy*, 2010, 35, (5), 2203–2209.

In the present work, performance of new configuration of micro-gas turbine cogeneration and tri-generation systems, with a steam ejector refrigeration system and heat recovery steam generator (HRSG) are studied. A micro-gas turbine cycle produces 200 KW power and exhaust gases of this micro-gas turbine are recovered in an HRSG. The main part of saturated steam in HRSG is used through a steam ejector refrigeration system to produce cooling in summer. In winter, this part of saturated steam is used to produce heating. In the first part of this paper, performance evaluation of this system with respect to energy utilization factor (EUF), fuel energy saving ratio (FESR), thermal efficiency, pinch point temperature difference, net power to evaporator cooling load and power to heat ratio is carried out. It has been shown that by using the present cogeneration system, one can save fuel consumption from about 23% in summer up to 33% in winter in comparison with separate generation of heating, cooling and electricity. In the second part of this paper, exergy analysis of the system has been done. It has been shown that combustion chamber; HRSG and heat exchanger are recognized as the largest sources of exergy losses respectively.

11/01122 Thermodynamic and carbon analyses of micro-generators for UK households

Allen, S. R. and Hammond, G. P. *Energy*, 2010, 35, (5), 2223–2234.

Micro-generators have the potential to reduce carbon emissions and enhance energy security by providing heat or electricity either from renewable sources, or via the more efficient use of fossil fuels. Such potential is often, however, unquantified or unclear, and hence a thermodynamic and related carbon analysis of micro-generators for UK household energy supply has been performed. Where pertinent, the thermodynamic concept of exergy is employed alongside that of energy. Analysis begins with a description of the established methods of energy supply to, and use within, typical UK households. On these foundations a grid-tied micro-wind turbine, a grid-tied solar photovoltaic array, and a solar hot-water system are analysed. Annual outputs are estimated and contextualized against the demands of representative households. The annual energy-resource and carbon savings provided by the micro-generators are determined on the basis that they (partially) displace the established supply systems. Savings are then compared with the energy-resource and carbon-emission 'debts' of the micro-generators, to assess the latter's net performance. Given appropriate installations, all three micro-generators are found to provide significant net energy and carbon benefits, confirming that all three technologies can provide net reductions in both carbon emissions and dependence on conventional energy resources.

11/01123 Thermodynamic and economic optimization of a MCFC-based hybrid system for the combined production of electricity and hydrogen

Verda, V. and Nicolin, F. *International Journal of Hydrogen Energy*, 2010, 35, (2), 794–806.

In this paper, a biogas fuelled power generation system is considered. The system is based on a molten carbonate fuel cell (MCFC) stack integrated with a micro gas turbine for electricity generation, coupled with a pressure swing absorption system (PSA) for hydrogen production. The aim of this work is the optimal design of the system plant considering thermodynamic and economic objective functions. Optimization is performed by modifying the design parameters characterizing the operation of the fuel cell, the reformer and the

microturbine. The corresponding costs and performances are obtained using a model developed at component level. Pinch analysis technique and a general heat exchanger network are used in order to select the optimal configuration of the heat exchangers. As a result, the Pareto front relating maximum efficiencies and minimum unit cost of electricity is obtained. The design corresponding with minimum cost of electricity, 0.036 €/kWh, is characterized by an electrical efficiency of about 0.46. The design corresponding with maximum efficiency, about 0.62, is characterized by a unit cost of electricity of 0.055 €/kWh. In the last part of the paper the effects produced by single variation of the design variables on unit cost of electricity and electrical efficiency are discussed.

11/01124 Turkey's short-term gross annual electricity demand forecast by fuzzy logic approach

Kucukali, S. and Baris, K. *Energy Policy*, 2010, 38, (5), 2438–2445.
This paper aims to forecast Turkey's short-term gross annual electricity demand by applying fuzzy logic methodology while general information on economical, political and electricity market conditions of the country is also given. Unlike most of the other forecast models about Turkey's electricity demand, which usually uses more than one parameter, gross domestic product based on purchasing power parity was the only parameter used in the model. Proposed model made good predictions and captured the system dynamic behaviour covering the years of 1970–2014. The model yielded average absolute relative errors of 3.9%. Furthermore, the model estimates a 4.5% decrease in electricity demand of Turkey in 2009 and the electricity demand growth rates are projected to be about 4% between 2010 and 2014. It is concluded that forecasting the Turkey's short-term gross electricity demand with the country's economic performance will provide more reliable projections. Forecasting the annual electricity consumption of a country could be made by any designer with the help of the fuzzy logic procedure described in this paper. The advantage of this model lies on the ability to mimic the human thinking and reasoning.

Economics, policy, supplies, forecasts

11/01125 A decarbonization strategy for the electricity sector: new-source subsidies

Johnson, K. C. *Energy Policy*, 2010, 38, (5), 2499–2507.
An expedient phase-out of carbon emissions in the electricity sector could be facilitated by imposing carbon fees and applying the revenue exclusively to subsidize new, low-carbon generation sources. Since there would initially be no 'new sources,' fees would be substantially zero at the outset of the program. Nevertheless, the program would immediately create high price incentives for low-carbon capacity expansion. Fees would increase as new, low-carbon sources gain market share, but price competition from a growing, subsidized clean-energy industry would help maintain moderate retail electricity prices. Subsidies would automatically phase out as emitting sources become obsolete.

11/01126 A grid based multi-objective evolutionary algorithm for the optimization of power plants

Dipama, J. *et al*. *Applied Thermal Engineering*, 2010, 30, (8–9), 807–816.
Economic and environmental restrictions, imposed on the design and operation of modern power plants, require the implementation of complex optimization strategies. Traditional optimization techniques (i.e. linear programming, gradient methods, etc.) usually transform the problem into relatively simple mathematical models, generally expressed as large systems of linear equations. However, the increasing complexity of contemporary energy conversion systems tends to make these methods either fail or very difficult to implement. This paper presents a multi-objective optimization method that permits solutions that simultaneously satisfy multiple conflicting objectives to be determined. The optimization process is carried out by using an evolutionary algorithm developed around an innovative technique that consists of partitioning the solution search space (i.e. a population of solutions) into parallel corridors. Within these corridors, 'header' solutions are trapped to be then involved in a reproduction process of new populations by using genetic operators. The proposed methodology is coupled to specific power plant models that are used to optimize two different power plants: (i) a cogeneration thermal plant and (ii) an advanced steam power station. In both cases the proposed technique has been shown to be very powerful, robust and reliable. Further, this methodology can be used as an effective tool to find the set of best solutions and thus providing a realistic support to the decision-making.

11/01127 A new spinning reserve requirement forecast method for deregulated electricity markets

Amjady, N. and Keynia, F. *Applied Energy*, 2010, 87, (6), 1870–1879.
Ancillary services are necessary for maintaining the security and reliability of power systems and constitute an important part of trade in competitive electricity markets. Spinning reserve (SR) is one of the most important ancillary services for saving power system stability and integrity in response to contingencies and disturbances that continuously occur in the power systems. Hence, an accurate day-ahead forecast of SR requirement helps the independent system operator (ISO) to conduct a reliable and economic operation of the power system. However, SR signal has complex, non-stationary and volatile behaviour along the time domain and depends greatly on system load. In this paper, a new hybrid forecast engine is proposed for SR requirement prediction. The proposed forecast engine has an iterative training mechanism composed of Levenberg–Marquadt learning algorithm and real coded genetic algorithm, implemented on the multi-layer perceptron neural network. The proposed forecast methodology is examined by means of real data of Pennsylvania–New Jersey–Maryland electricity market and the California ISO controlled grid. The obtained forecast results are presented and compared with those of the other SR forecast methods.

11/01128 Climate change and electricity consumption – witnessing increasing or decreasing use and costs?

Pilli-Sihvola, K. *et al*. *Energy Policy*, 2010, 38, (5), 2409–2419.
Climate change affects the need for heating and cooling. This paper examines the impact of gradually warming climate on the need for heating and cooling with an econometric multivariate regression model for five countries in Europe along the south–north line. The predicted changes in electricity demand are then used to analyse how climate change impacts the cost of electricity use, including carbon costs. The main findings are, that in central and north Europe, the decrease in heating due to climate warming, dominates and thus costs will decrease for both users of electricity and in carbon markets. In southern Europe climate warming, and the consequential increase in cooling and electricity demand, overcomes the decreased need for heating. Therefore costs also increase. The main contributors are the role of electricity in heating and cooling, and the climatic zone.

11/01129 Dynamics of risk management tools and auctions in the second phase of the Brazilian electricity market reform

de Souza, F. C. and Loureiro Legey, L. F. *Energy Policy*, 2010, 38, (4), 1715–1733.
In 2004, the reform of the Brazilian electricity market underwent a thorough revision. One of its causes was the electricity rationing that began in June 2001 and lasted until February 2002. Among other measures, the 2004 revision devised new mechanisms intended to reduce risks associated to contracts settled in electricity auctions and those related to investments in new generation plants. As 4 years have passed since the onset of the reform's revision, sufficiently enough data are now available for an analysis of the post-revision dynamics of the Brazilian electricity market. This is the purpose of the present paper, which focuses on the dynamics of the different types of electricity auctions and on the so-called mechanism for compensation of surpluses and deficits, both created in the wake of the 2004 revision. The ultimate goal is to understand the behaviour of the agents involved in auctions – notably buyers and sellers of electricity – and propose remedial actions to eliminate existing loopholes in the present regulatory framework. To achieve this goal, four steps were necessary. First, a database to support the analysis was built. Then, the main drivers of the dynamics of the risk management tools were identified. Finally, consequences of the implemented changes were discussed and corrections for observed pitfalls proposed.

11/01130 Ecological efficiency in CHP: biodiesel case

Coronado, C. R. *et al*. *Applied Thermal Engineering*, 2010, 30, (5), 458–463.
This paper evaluates and quantifies the environmental impact resulting from the combination of biodiesel fuel (pure or blended with diesel), and diesel combustion in thermoelectric power plants that utilize combined cycle technology. In regions without natural gas, the option was to utilize diesel fuel; the consequence would be a greater emission of pollutants. Biodiesel is a renewable fuel which has been considerably interesting in Brazil power matrix in recent years. The concept of ecological efficiency, largely evaluates the environmental impact caused by CO_2, SO_2, NO_x and particle matter emissions. The pollution resulting from biodiesel and diesel combustion is analysed, separately considering CO_2, SO_2, NO_x and particulate matter gas emissions, and comparing them international standards currently used regarding air quality. It can be concluded that it is possible to calculate the qualitative environmental factor, and the ecological effect, from a thermoelectric power plant utilizing central heat power of combined cycle. The ecological efficiency for pure biodiesel fuel (B100) is 98.16%; for biodiesel blended with conventional diesel fuel, B20 (20% biodiesel

and 80% diesel) is 93.19%. Finally, ecological efficiency for conventional diesel is 92.18%, as long as a thermal efficiency of 55% for thermoelectric power plants occurs.

11/01131 Electricity demand load forecasting of the Hellenic power system using an ARMA model

Pappas, S. Sp. *et al. Electric Power Systems Research*, 2010, 80, (3), 256–264.

Effective modelling and forecasting requires the efficient use of the information contained in the available data so that essential data properties can be extracted and projected into the future. As far as electricity demand load forecasting is concerned time series analysis has the advantage of being statistically adaptive to data characteristics compared to econometric methods which quite often are subject to errors and uncertainties in model specification and knowledge of causal variables. This paper presents a new method for electricity demand load forecasting using the multi-model partitioning theory and compares its performance with three other well-established time series analysis techniques namely corrected Akaike information criterion, Akaike's information criterion and Schwarz's Bayesian information criterion. The suitability of the proposed method is illustrated through an application to actual electricity demand load of the Hellenic power system, proving the reliability and the effectiveness of the method and making clear its usefulness in the studies that concern electricity consumption and electricity prices forecasts.

11/01132 Electricity market price spike analysis by a hybrid data model and feature selection technique

Amjady, N. and Keynia, F. *Electric Power Systems Research*, 2010, 80, (3), 318–327.

In a competitive electricity market, energy price forecasting is an important activity for both suppliers and consumers. For this reason, many techniques have been proposed to predict electricity market prices in the recent years. However, electricity price is a complex volatile signal owning many spikes. Most of electricity price forecast techniques focus on the normal price prediction, while price spike forecast is a different and more complex prediction process. Price spike forecasting has two main aspects: prediction of price spike occurrence and value. In this paper, a novel technique for price spike occurrence prediction is presented composed of a new hybrid data model, a novel feature selection technique and an efficient forecast engine. The hybrid data model includes both wavelet and time domain variables as well as calendar indicators, comprising a large candidate input set. The set is refined by the proposed feature selection technique evaluating both relevancy and redundancy of the candidate inputs. The forecast engine is a probabilistic neural network, which are fed by the selected candidate inputs of the feature selection technique and predict price spike occurrence. The efficiency of the whole proposed method for price spike occurrence forecasting is evaluated by means of real data from the Queensland and PJM electricity markets.

11/01133 Electricity regulation and electricity market reforms in China

Ngan, H. W. *Energy Policy*, 2010, 38, (5), 2142–2148.

The electricity industry of China has been in a process of reforms since the 1980s. This paper gives a review on the three main stages of reforms in China so as to trace out key features of various reform measures including those for power investment financing, the separation between government and power enterprises, and the division between power generation firms and power grids. The findings suggest that further regulatory change in China's electricity market reform is necessary when integration of the electricity markets and increased competition are paving the way ahead for a market-oriented structure. Prospective electricity regulation in the form of a strong legal system and effective institutions that protect market competition and promote appropriate incentives for efficiency are suggested in the paper.

11/01134 Modeling and analysis of strategic forward contracting in transmission constrained power markets

Yu, C. W. *et al. Electric Power Systems Research*, 2010, 80, (3), 354–361.

Taking the effects of transmission network into account, strategic forward contracting induced by the interaction of generation firms' strategies in the spot and forward markets is investigated. A two-stage game model is proposed to describe generation firms' strategic forward contracting and spot market competition. In the spot market, generation firms behave strategically by submitting bids at their nodes in a form of linear supply function (LSF) and there are arbitrageurs who buy and resell power at different nodes where price differences exceed the costs of transmission. The owner of the grid is assumed to ration limited transmission line capacity to maximize the value of the transmission services in the spot market. The Cournot-type competition is assumed for the strategic forward contract market. This two-stage model is formulated as an equilibrium problem with equilibrium constraints (EPEC); in which each firm's optimization problem in the forward market is a mathematical program with equilibrium constraints (MPEC) and parameter-dependent spot market equilibrium as the inner problem. A non-linear complementarity method is employed to solve this EPEC model.

11/01135 Normal boundary intersection method for suppliers' strategic bidding in electricity markets: an environmental/economic approach

Vahidinasab, V. and Jadid, S. *Energy Conversion and Management*, 2010, 51, (6), 1111–1119.

In this paper the problem of developing optimal bidding strategies for the participants of oligopolistic energy markets is studied. Special attention is given to the impacts of suppliers' emission of pollutants on their bidding strategies. The proposed methodology employs supply function equilibrium (SFE) model to represent the strategic behaviour of each supplier and locational marginal pricing mechanism for the market clearing. The optimal bidding strategies are developed mathematically using a bilevel optimization problem where the upper-level subproblem maximizes individual supplier payoff and the lower-level subproblem solves the independent system operator's market clearing problem. In order to solve market clearing mechanism the multiobjective optimal power flow is used with supplier emission of pollutants, as an extra objective, subject to the supplier physical constraints. This paper uses normal boundary intersection approach for generating Pareto optimal set and then fuzzy decision making to select the best compromise solution. The developed algorithm is applied to an IEEE 30-bus test system. Numerical results demonstrate the potential and effectiveness of the proposed multiobjective approach to develop successful bidding strategies in those energy markets that minimize generation cost and emission of pollutants simultaneously.

11/01136 Nuclear electricity for sustainable development: Egypt a case study

Comsan, M. N. H. *Energy Conversion and Management*, 2010, 51, (9), 1813–1817.

Egypt is a fast growing country with 78.9 million population and annual per capita installed power 0.286 MW as of July 2008. Moderate to mature population and economic growth trends forecast population and annual per capita installed power to reach 111 millions and 0.63 MW, respectively by 2032; and 128 millions at per capita power of 1.02 MW by 2052. With these trends in consideration installed electricity generation capacity are forecasted at 70 GW by 2032 and 132 GW by 2052 as compared to the 2008 installed power of 22.6 GW. Meeting these demands is almost impossible using known limited national fossil fuel reserves. Current electricity generation policy exhausts about 65% of country's total fossil production. Crude oil reserves are expected to deplete by 2012, while gas reserves will be overstrained starting from 2030. A major policy shift towards the use of non-fossil resources is to be adopted. In the article Egypt's major primary energy resources are evaluated. Electricity generation plans till 2022 are presented and an electricity generation strategy based on gradual introduction of nuclear power starting from 2018 is outlined. A balanced generation mix based on 72.7% fossil, 13% nuclear and 14.3% renewables is targeted by 2052. The mix is supposed to meet Egypt's electricity needs by 2052 and to improve country's energy sustainability.

11/01137 Price transmission in the UK electricity market: was NETA beneficial?

Giulietti, M. *et al. Energy Economics*, 2010, 32, (5), 1165–1174.

This paper explores the relationship between domestic retail electricity prices in Britain and their determinants in the context of the new electricity trading arrangements (NETA) introduced in 2001. The authors employ a consistent comparison of wholesale power price series before and after NETA, alongside a difference-in-differences analysis based on using Scotland as a control. Despite NETA's stated intention of reducing wholesale and thereby retail prices, it is concluded that its net effect, alongside other developments, instead merely rearranged where money was made in the system.

11/01138 Regulation strategies of cogeneration of heat and power (CHP) plants and electricity transit in Denmark

Østergaard, P. A. *Energy*, 2010, 35, (5), 2194–2202.

Denmark is in a situation with many scattered sources of electricity that are not controlled by the central load dispatch. At the same time, Denmark is being used as an electricity transit corridor between the hydro-based systems of Norway/Sweden and the thermal systems of Germany and continental Europe. Through energy systems analyses and load-flow analyses, it is determined that if geographically scattered load balancing utilizing the regulation ability of hitherto locally controlled plants is introduced while also introducing new dispatchable loads in the form of electric vehicles and heat pumps, electricity transit is enabled to a higher degree than if central load balancing is maintained. This is the case of an intact transmission system as well as a system with inoperative transmission lines. With an intact system,

the average load of the system is approximately halved when applying scattered load balancing. Utilizing the regulating capacity of local plants thus improves the role of the Danish system in the northern European system.

11/01139 Structural analysis of electricity consumption by productive sectors. The Spanish case
Alcántara, V. *et al. Energy*, 2010, 35, (5), 2088–2098.
The aim of this paper is to identify those sectors that contribute most to electricity consumption in Spain, using a methodology based on input–output tables, and to derive some recommendations aimed at increasing energy efficiency in those sectors. This input–output approach is complemented with a sector-focused study in which the availability of electricity-efficient technologies per sector and the barriers to their uptake are identified. This hybrid approach is deemed useful to derive policy implications.

11/01140 The potential for electricity generation from crop and forestry residues in Spain
Gómez, A. *et al. Biomass and Bioenergy*, 2010, 34, (5), 703–719.
The authors assess the energy contents of agricultural and forestry residues in Spain, and the potential for the generation of electricity from them. The methodology employed is a hierarchical, GIS-based one, and leads through the physical, geographical and technical potential to the economic analysis. The results from the latter are crafted in the form of generation-cost curves, which provide a good indication of how the cost of the energy increases as the generation from these residues does. Geo-referenced data allow for the consideration of the opposing influences on the specific cost of the plant size and the transport costs, which are both incorporated in the model by means of a plant supply area. A representative cost is defined and used to compare costs among biomass sources and combustion technologies. The combined technical potential of agriculture and forestry residues is 118 PJ y^{-1} (equivalent to 11.25% of the net electric energy generated in Spain in 2008). The economic potential (defined as the potential with a cost smaller than the representative one) is 46.3 PJ y^{-1} (or 4.43% of net electric energy generated in Spain in 2008).

11/01141 The relationship between spot and futures prices in the Nord Pool electricity market
Botterud, A. *et al. Energy Economics*, 2010, 32, (5), 967–978.
The authors analyse 11 years of historical spot and futures prices from the hydro-dominated Nord Pool electricity market. Futures prices tended to be higher than spot prices. The average convenience yield is therefore negative, but varies by season and depends on the storage levels in hydro reservoirs. The average realized return on holding a long position in the futures market is also negative. The negative convenience yield and risk premium contrast empirical findings in most other commodity markets. The authors argue that differences between the supply and demand sides in terms of risk preferences and the ability to take advantage of short-term price variations can contribute to explain the observed relationship between spot and futures prices. In addition, the analysis shows that the relationship between spot and futures prices is clearly linked to the physical state of the system, such as hydro inflow, reservoir levels, and demand.

07 STEAM RAISING

Boiler operation/design

11/01142 A steam generator model identification and robust H_∞ controller design with ν-gap metric for a feedwater control system
Sohn, J. J. and Seong, P. H. *Annals of Nuclear Energy*, 2010, 37, (2), 180–195.
This study presents a robust H_∞ controller for the feedwater system of KSNP (Korean standard nuclear power plant) vertical U-tube type steam generators (UTSG). As the first step of the controller development, a precise thermal–hydraulic model for the steam generator is built. A series of model experiments are performed using the developed thermal–hydraulic model in order to acquire the input–output data sets which represent steam generator characteristics. These data sets are utilized to build simplified steam generator models for control through a system identification algorithm, 'Simple Process Models'. Among the developed steam generator models, the representative models for the designated power ranges are selected by a criterion of ν-gap metric. The representative robust controllers for the selected models are designed utilizing the loop-shaping H_∞ design technique. Finally, the robustness and performance of the proposed controllers are validated and compared against those of PI (proportional–integral) controller. The validation results demonstrated that the proposed H_∞ robust controller has a superior robustness and an enhanced control performance.

11/01143 Energy, exergy and economic analysis of industrial boilers
Saidur, R. *et al. Energy Policy*, 2010, 38, (5), 2188–2197.
In this paper, the useful concept of energy and exergy utilization is analysed, and applied to the boiler system. Energy and exergy flows in a boiler have been shown in this paper. The energy and exergy efficiencies have been determined as well. In a boiler, the energy and exergy efficiencies are found to be 72.46% and 24.89%, respectively. A boiler energy and exergy efficiencies are compared with others work as well. It has been found that the combustion chamber is the major contributor for exergy destruction followed by heat exchanger of a boiler system. Furthermore, several energy saving measures such as use of variable speed drive in boiler's fan energy savings and heat recovery from flue gas are applied in reducing a boiler energy use. It has been found that the payback period is about 1 year for heat recovery from a boiler flue gas. The payback period for using VSD with 19 kW motor found to be economically viable for energy savings in a boiler fan.

11/01144 Exergy analysis of a thermal power plant with measured boiler and turbine losses
Regulagadda, P. *et al. Applied Thermal Engineering*, 2010, 30, (8–9), 970–976.
In this paper, a thermodynamic analysis of a subcritical boiler–turbine generator is performed for a 32 MW coal-fired power plant. Both energy and exergy formulations are developed for the system. A parametric study is conducted for the plant under various operating conditions, including different operating pressures, temperatures and flow rates, in order to determine the parameters that maximize plant performance. The exergy loss distribution indicates that boiler and turbine irreversibilities yield the highest exergy losses in the power plant. In addition, an environmental impact and sustainability analysis are performed and presented, with respect to exergy losses within the system.

11/01145 Exergy-based performance analysis for proper O&M decisions in a steam power plant
Ray, T. K. *et al. Energy Conversion and Management*, 2010, 51, (6), 1333–1344.
Exergy analysis of a 500 MWe steam turbine cycle of an operating power plant is conducted under the design and off-design conditions with different degrees of superheat and reheat sprays. The analysis shows how a first law-based analysis shows an apparent (false) improvement in a feed water heater under an off-design condition, while the actual performance degradation is reflected through an exergy analysis. The analysis also helps identifying the contribution of individual equipment in the overall increase of exergy destruction under off-design condition. Exergy analysis is also performed using off-line performance guarantee (PG) tests conducted before and after a unit overhauling. Pre-overhauling exergy efficiency figures of the major cycle equipment are compared with their respective design values to assess the need and extent of maintenance work, whereas post-overhaul exergy data is used to quantify the compliance with the guaranteed performance. Results of the study provide a quantifiable basis for formulating exergy–economy driven maintenance scheduling and PG test procedures.

11/01146 Full-scale co-firing trial tests of sawdust and bio-waste in pulverized coal-fired 230 t/h steam boiler
Zuwala, J. and Sciazko, M. *Biomass and Bioenergy*, 2010, 34, (8), 1165–1174.
Co-firing trial tests of sawdust and bio-waste coming from cereal production with hard coal were carried out at Skawina power plant in Poland (1532 MW in fuel, currently belonging to CEZ Group). Skawina power plant is a tangentially fired pulverized coal unit with nine boilers (four boilers of 210 t/h and five boilers of 230 t/h live steam respectively) that produces 590 MW electricity and 618 MW of heat (district heating and process steam). The paper presents an analysis of energy and ecological effects of sawdust and bio-waste co-firing in the existing pulverized hard coal boiler. The mixture of coal and biomass was blended in the coal yard, and fed into the boiler through the coal mills. During the tests, combustion of mixtures composed of hard coal and sawdust (with mass share of 9.5%) and hard coal – bio-waste (6.6% mass basis) were examined. The co-firing tests were successful. Based on the analysis of the test results, the influence of biomass co-firing on specific components of energy balance (e.g. stack losses and boiler thermal efficiency) was discussed, in comparison to combustion of coal alone. The emission indices during coal combustion were calculated

and compared to the emission indices for biomass co-firing. It was proved that co-firing of both biomass sorts leads to a decrease of CO and SO_2 emissions.

11/01147 Piecewise affine modeling and control of a boiler–turbine unit

Keshavarz, M. *et al. Applied Thermal Engineering*, 2010, 30, (8–9), 781–791.

In this paper, a discrete-time piecewise affine (PWA) model has been proposed for a nonlinear model of boiler–turbine unit using plant operating points. PWA model is one of the main classes of hybrid systems being equivalent to some other hybrid modelling frameworks such as mixed logical dynamical (MLD) model. In order to control the system, a model predictive control (MPC) strategy in explicit form has been used which calculates the control law as an affine function of system states. In this method, the computation of MPC is moved off-line. The off-line control law is easier to implement reducing to a look-up table in comparison with the on-line approach. Finally, the explicit model predictive control performance has been compared with the linear controller obtained using H_∞ approach. The results are illustrated by simulations. They show that the explicit MPC method has suitably improved the system performance, especially the quantity of control efforts is smaller and without saturation compared with that of H_∞ control system.

08 COMBUSTION

Burners, combustion systems

11/01148 3-D temperature and stress distributions of strip in preheating furnace of continuous annealing line

Chen, T.-C. *et al. Applied Thermal Engineering*, 2010, 30, (8–9), 1047–1057.

The cold-rolled steel sheets produced by continuous annealing line (CAL) exhibit a significant phenomenon of warping during punching process. The phenomenon of warping is attributed to the non-uniform residual stress of steel strip, which may result from the non-uniform distributions of the temperature and plastic deformation along both the width and thickness of strip when it passes through the rolls in the CAL. In this study, only the distributions of the temperature and thermal stresses of strip in the preheating zone, one of several zones in CAL, are investigated first. Both the thermal and mechanical analyses are performed by using the finite element code ANSYS to investigate the effects of heating conditions in the preheating furnace. The equivalent emission of radiation of the strip corresponding to the complicated furnace environment is evaluated inversely with the aid of strip temperature estimated by energy balance model. Moreover, three-dimensional (3-D) distributions of the temperature and deformation of strip are then iteratively evaluated by the energy and mechanical models due to their coupling effect until a satisfied convergence in numerical solutions is obtained. The results show that the taper rolls tend to introduce a significantly non-uniform distribution of the temperature along the width. This temperature pattern might lead to an unfavorable consequence of enormously non-uniform distribution of stress along the width.

11/01149 An evaluation of biomass co-firing in Europe

Al-Mansour, F. and Zuwala, J. *Biomass and Bioenergy*, 2010, 34, (5), 620–629.

Reduction of the emissions of greenhouses gases, increasing the share of renewable energy sources (RES) in the energy balance, increasing electricity production from renewable energy sources and decreasing energy dependency represent the main goals of all current strategies in Europe. Biomass co-firing in large coal-based thermal power plants provides a considerable opportunity to increase the share of RES in the primary energy balance and the share of electricity from RES in gross electricity consumption in a country. Biomass-coal co-firing means reducing CO_2 and SO_2, emissions and it may also reduce NO_x emissions, and also represents a near-term, low-risk, low-cost and sustainable energy development. Biomass-coal co-firing is the most effective measure to reduce CO_2 emissions, because it substitutes coal, which has the most intensive CO_2 emissions per kWh electricity production, by biomass, with a zero net emission of CO_2. Biomass co-firing experience worldwide are reviewed in this paper. Biomass co-firing has been successfully demonstrated in over 150 installations worldwide for most combinations of fuels and boiler types in the range of 50–700 MWe, although a number of very small plants have also been involved. More than a hundred of these have been in Europe. A key indicator for the assessment of biomass co-firing is intrduced and used to evaluate all available biomass co-firing technologies.

11/01150 Batch testing of solid fuels with ilmenite in a 10 kW_{th} chemical-looping combustor

Berguerand, N. and Lyngfelt, A. *Fuel*, 2010, 89, (8), 1749–1762.

Batch experiments were conducted in a 10 kW_{th} chemical-looping combustor for solid fuels using ilmenite, an iron titanium oxide, as the oxygen carrier with two solid fuels: a petroleum coke from Mexico and a bituminous coal from South Africa. The purpose of these batch tests was to attain detailed information on fuel conversion, complementary to previous continuous operation of the unit. At steady-state, a fuel batch of typically 25 g was introduced in the fuel reactor and gas concentrations were measured at the outlet of both air and fuel reactors. The fuel reactor was fluidized with steam and the amount of bed material was typically 5 kg. The fuel introduced devolatilizes rapidly while the remaining char is gasified and the resulting syngases H_2 and CO react with the oxygen carrier. Operation involved testing at different fuel reactor temperatures from 950 to 1030 °C, and investigation of the influence of particle circulation between air and fuel reactors. The fuel conversion rate was increased at higher temperature: at 950 °C the instantaneous rate of conversion for petroleum coke averaged at 17.4%/min while at 1030 °C, the value was 40%/min. For the much more reactive South African coal, the averaged rate at 970 °C was 47%/min and increased to 101%/min at 1000 °C. For petroleum coke testing with particle circulation, the oxygen demand – defined as oxygen lacking to fully convert the gases leaving the fuel reactor – was typically 12–14% for the gasified char including H_2S, in line with previous experiments with the same unit and fuel. If only syngases are considered, the oxygen demand for char conversion was 8.4–11%. Similar or even lower values were seen for the char of South African coal. This is in line with expectations, i.e. that it is possible to reach fairly high conversion, although difficult to reach complete gas conversion with solid fuel. It was also seen that the volatiles pass through the system essentially unconverted, an effect of feeding the fuel from above. Moreover, the oxygen demand for char conversion decreased with increasing temperature. Finally, the CO_2 capture – defined as the proportion of gaseous carbon leaving the fuel reactor to total gaseous carbon leaving the system – decreased at higher particle circulation and a correlation between capture and circulation index was obtained.

11/01151 Burning of coal waste piles from Douro Coalfield (Portugal): petrological, geochemical and mineralogical characterization

Ribeiro, J. *et al. International Journal of Coal Geology*, 2010, 81, (4), 359–372.

Anthracites have exploited in the Douro coalfield for many years (1795–1994). Besides many small mines Douro Coalfield had two principal mining areas (S. Pedro da Cova and Pejao). Coal mining activities cause several impacts on the environment, one of which is the amount of discard or waste which was disposed of all over Douro coalfield resulting in one of the most significant and severe impacts on the environment. Over 20 waste piles exist in the old mining areas, geographically dispersed, and three of them are presently burning. Their ignition was caused by forest fires during the summer of 2005. Samples from the burning and unburned zones of the waste piles were studied as were the gas from vents and the minerals resulting after combustion. Geochemical processes and mineralogical transformations in the burning coal waste pile were investigated. Microscopic analyses of the samples identified some particular aspects related with combustion: oxidation of pyrite, the presence of iron oxides, organic particles with cracks and rims with lowered (suppressed) Rr, devolatilization vacuoles and some char structures. The occurrence of vitreous (glassy) material as well as Fe–Al spinels in the burning coal waste provide evidences that the combustion temperature could have reached values above 1000 °C. Due to combustion, and as expected, the samples studied reported high ash yields. Samples taken from the burning zones reported an increase of As, Cr, Li, Nb, Ni, Pb, Rb, Sr and LREE concentrations and a decrease in Zr and HREE concentrations. Enrichment in Cs, Li and Rb was noted when comparing with the geochemical composition of black shales and world coals composition that is related with the contribution of granitic rocks in the sediments that originated the main lithologies of the Douro Coalfield (carbonaceous shale and lithic arenites). Cluster analyses (R-type and Q-type) were performed to understand the trend between the unburned and burning samples and it seems that some chemical variations are responsible for this separation. Elemental sulfur and salammoniac (ammonium salt) are the coal fire gas minerals neoformed on the surface of piles, near the burning zones. They were identified by different techniques, mainly SEM-EDX, XRD and FTIR. Relatively high concentrations of several aromatic compounds were detected in the gas collected at the studied areas, as well as aliphatic hydrocarbons. The highest concentrations of aromatic hydrocarbons

were measured in gas samples from S. Pedro da Cova waste pile. The exposure to hazardous compounds present in the gas is a serious risk to human health and the environment.

11/01152 Catalytic oxidation kinetics of iron-containing carbon particles generated by spraying ferrocene-mixed with diesel fuel into a hydrogen–air diffusion flame

Kim, Y. H. *et al. Carbon*, 2010, 48, (7), 2072–2084.

Kinetic measurements of the catalytic oxidation of iron-containing soot particles were made for a better understanding of the role of catalytic particles in the initiation of soot oxidation. Carbon-based iron-containing soot particles were generated by spraying ferrocene-mixed with diesel fuel into an oxy-hydrogen flame. A commercial carbon black was used as a standard. Their oxidative kinetics and physico-chemical characteristics were measured by thermogravimetric analysis, secondary ion mass spectrometry, X-ray diffraction, gas-cell Fourier-transform infrared spectroscopy, induced coupled plasma-atomic emission spectroscopy and high-resolution transmission electron microscopy. It was found that a tiny amount of ferrocene led to a significant reduction in both the on-set temperature and the activation energy of soot oxidation. Catalytic oxidation occurred in two consecutive steps, as temperature increased. The initiation of oxidation, even with an addition of ferrocene, was controlled mainly by surface oxygen complexes and partly by the long-range crystalline order of the carbon graphene layer. However, once catalytic oxidation began, the progress of the reaction was mainly determined by the amount of ferrocene that was added.

11/01153 Catalytic soot combustion over CeO_2-based oxides

Muroyama, H. *et al. Catalysis Today*, 2010, 153, (3–4), 133–135.

The catalytic soot combustion, surface area, and reducibility for the CeO_2-based oxides were investigated. Carbon black (CB), which was used as a model of soot particle, was combusted over 700 °C, while the CeO_2-based catalysts reduced the CB oxidation temperature by more than 150 °C. Although the addition of rare-earth metal oxides to CeO_2 increased the surface area, no remarkable improvement of catalytic activity was confirmed. The transition metal oxide added to CeO_2 significantly promoted the oxidation reaction, and the CuO–CeO_2 catalyst exhibited the highest activity despite the lowest surface area of all composite oxides investigated. The reduction behaviour of catalysts was closely related with the activity of CB oxidation. It was indicated that the oxygen species available for the oxidation reaction was increased by the addition of transition metal components. When the Cu content was varied for the CuO–CeO_2 catalyst, the optimal amount existed for the CB oxidation.

11/01154 CFD analysis of the effects of co-firing biomass with coal

Ghenai, C. and Janajreh, I. *Energy Conversion and Management*, 2010, 51, (8), 1694–1701.

Computational fluid dynamics (CFD) analysis of the effects of co-firing biomass with coal is presented in this study. Coal/biomass co-firing is a complex problem that involves gas and particle phases, along with the effect of the turbulence on the chemical reactions. The CFD analysis includes the prediction of volatile evolution and char burnout from the co-pulverized coal/biomass particles along with the simulation of the combustion chemistry occurring in the gas phase. The mathematical models consist of models for turbulent flow (RNG k–ε model); gas phase combustion (two-mixture fractions/PDF model); particles dispersion by turbulent flow (stochastic tracking model); coal/biomass particles devolatilization (two competing rates Kobayashi model); heterogeneous char reaction (kinetics/diffusion-limited rate model); and radiation (P-1 radiation model). The coal used is a Canadian high sulfur bituminous coal. The coal was blended with 5–20% wheat straw (thermal basis) for co-firing. The effect of the percentage of biomass blended with coal on the flow field, gas and particle temperature distribution, particles trajectories and gas emissions (CO_2 and NO_x) are presented. One important result is the reduction of NO_x and CO_2 emissions when using co-combustion. This reduction depends on the proportion of biomass (wheat straw) blended with coal.

11/01155 Co-firing used engine lubrication oil with LPG in furnaces

Al-Omari, S. A.-B. *et al. Energy Conversion and Management*, 2010, 51, (6), 1259–1263.

Combustion and heat transfer characteristics obtained based co-firing LPG with used engine oils (UEO) in a furnace, are investigated experimentally. In an attempt to assess UEO as a fuel, the UEO-based results are compared with results obtained using two other fuels, namely diesel, and a used cooking oil (UCkO). To ease its admission to the furnace and its subsequent vaporization and combustion, UEO is preheated by allowing it to flow upwardly in a vertical pipe surrounded by hot gases generated from LPG combustion. UEO that reaches the tip of the pipe un-vaporized, spills and hence has the chance to further heatup and vaporize as it exchanges heat with the upwardly flowing LPG combustion gases, in a counter flow process. Runs are divided into three groups based on the mass ratio of the liquid-fuel/LPG and the mass flow rate of the LPG supplied to the furnace. Ranges of these quantities over which UEO qualify as a good fuel and/or good promoter to radiation have been identified.

11/01156 Comprehensive sulfation model verified for T–T sorbent clusters during flue gas desulfurization at moderate temperatures

Li, Y. *et al. Fuel*, 2010, 89, (8), 2081–2087.

An empirical sulfation model for T–T sorbent clusters was developed based on amassed experimental results under moderate temperatures (300–800 °C). In the model, the reaction rate is a function of clusters mass, SO_2 concentration, CO_2 concentration, calcium conversion and temperature. The smaller pore volume partly results in a lower reaction rate at lower temperatures. The exponent on SO_2 concentration is 0.88 in the rapid reaction stage and then decreases gradually as reaction progresses. The exponent on the fraction of the unreacted calcium is one-third in the first stage and then increases significantly in the second stage. The CO_2 concentration has a negative influence on SO_2 removal, especially for the temperature range of 400–650 °C, which should be avoided to achieve a high effective calcium conversion. The sulfation model has been verified for the T–T sorbent clusters and has also been applied to CaO particles. Over extensive reaction conditions, the predictions agree well with experimental data.

11/01157 Correlating the effects of ash elements and their association in the fuel matrix with the ash release during pulverized fuel combustion

Shah, K. V. *et al. Fuel Processing Technology*, 2010, 91, (5), 531–545.

During pulverized fuel combustion, inorganic elements such as alkalis, sulfur, chlorine, calcium and magnesium, as well as a range of minor elements are partly released into the gas phase. These gas-borne species can nucleate, coagulate and condense to form either aerosol particles or sticky layers on ash particles, leading to ash deposition and corrosion problems in power utilities. Furthermore, the fine aerosols can lead to harmful gaseous and particulate emissions. It is well documented that the mode of occurrence and the chemical speciation of ash forming elements in the coal/biomass structure are important for the release behaviour of mineral components. In the presented work, this is investigated by performing quantitative elemental investigations of ash releases for two different coals (a Polish and a British coal) and six diverse biomass fuels (wood bark, wood chips, waste wood, olive residue, sawdust and straw). The tests are performed within the lab-scale combustion simulator) of the Energy Research Centre of the Netherlands. The operating conditions applied were that of a typical pulverized fuel (PF) fired boiler, i.e. atmospheric pressure, high temperatures of 1400–1650 °C, and high heating rate of 10^5 K/s. Gas phase elemental release of alkalis, sulfur, chlorine, calcium and magnesium has been quantified at relevant high carbon conversion levels. With the performed set of experiments several of the past observations from the literature are reconfirmed. In addition to this, based on the extensive data pool at hand, a simple but reliable ($R^2 > 0.95$) set of linear correlations have been proposed to predict the elemental release of potassium, sodium, chlorine and sulfur. It is also concluded that such linear expressions can be particularly effective for the prediction of elemental release from the fuels of similar characteristics, such as woody biomass.

11/01158 Effect of reactivity loss on apparent reaction order of burning char particles

Murphy, J. J. and Shaddix, C. R. *Combustion and Flame*, 2010, 157, (3), 535–539.

Considerable debate still exists in the char combustion community over the expected and observed reaction orders of carbon reacting with oxygen. In particular, very low values of the reaction order (approaching zero) are commonly observed in char combustion experiments. These observations appear to conflict with porous catalyst theory as first expressed by Thiele, which suggests that the apparent reaction order must be greater than 0.5. In this work, it is proposed that this conflict may be resolved by considering the decrease in char reactivity with burnout due to ash effects, thermal annealing, or other phenomena. Specifically, the influence of ash dilution of the available surface area on the apparent reaction order is explored. Equations describing the ash dilution effect are combined with a model for particle burnout based on single-film nth-order Arrhenius char combustion and yield an analytical expression for the effective reaction order. When this expression is applied for experimental conditions reflecting combustion of individual pulverized coal particles in an entrained flow reactor, the apparent reaction order is shown to be lower than the inherent char matrix reaction order, even for negligible extents of char conversion. As char conversion proceeds and approaches completion, the apparent reaction order drops precipitously past zero to negative values. Conversely, the inclusion of the ash

dilution model has little effect on the char conversion profile or char particle temperature until significant burnout has occurred. Taken together, these results suggest that the common experimental observation of low apparent reaction orders during char combustion is a consequence of the lack of explicit modelling of the decrease in char reactivity with burnout.

11/01159 Evaporation and condensing augmentation of water droplets in flue gas

Miliauskas, G. *et al. International Journal of Heat and Mass Transfer*, 2010, 53, (5–6), 1220–1230.

The unsteady heat and mass transfer of sprayed water in the flue gas is modelled according to the iterative method of numerical research. The complex 'droplet problem' covers the analysis of combined energy transfer in a semitransparent droplet, also combined heating and evaporation of the droplet. The surface temperature of the evaporating droplet is determined, at which the balance of energy fluxes taken to the surface and taken from the surface is reached. The thermal state mode of an evaporating droplet depends on the way of droplet heating as well. The change of thermal state and phase transformations parameters of water droplets warming in flue gas is analysed in the universal time scale. The initial evaluation of heat energy accumulated in exhaust flue gas utilization by water injection is presented.

11/01160 Experimental flame speed in multi-layered nano-energetic materials

Manesh, N. A. *et al. Combustion and Flame*, 2010, 157, (3), 476–480.

This paper deals with the reaction of dense metastable intermolecular composite materials, which have a higher density than conventional energetic materials. The reaction of a multilayer thin film of aluminium and copper oxide has been studied by varying the substrate material and thicknesses. The in-plane speed of propagation of the reaction was experimentally determined using a time-of-flight technique. The experiment shows that the reaction is completely quenched for a silicon substrate having an intervening silica layer of less than 200 nm. The speed of reaction seems to be constant at 40 m/s for silica layers with a thickness greater than 1 μm. Different substrate materials such as glass and photoresist were also used.

11/01161 Flame structure of LPG-air inverse diffusion flame in a backstep burner

Mahesh, S. and Mishra, D. P. *Fuel*, 2010, 89, (8), 2145–2148.

The present experimental study characterizes the turbulent LPG inverse diffusion flame (IDF) stabilized in a backstep burner in terms of visible flame length, dual flame structure, centreline temperature distribution, and oxygen concentration. The visible flame length for a fixed fuel jet velocity is found to reduce with increase in air jet velocity. Besides this, the effect of air and fuel jet velocities on visible flame length is interpreted using a new parameter, global momentum ratio (GMR). Interestingly, GMR seems to be correlating well with the visible flame length for the air and fuel velocity ranges considered in the present study. Moreover, the dual flame structure of IDF is identified with the help of CH-chemiluminescence signature. The existence of dual flame structure of IDF is confirmed further with the centreline temperature and oxygen concentration measurements.

11/01162 Fuels combustion effects on a passive mode silver/alumina HC-SCR catalyst activity in reducing NO_x

Theinnoi, K. *et al. Chemical Engineering Journal*, 2010, 158, (3), 468–473.

The activity of a Ag/Al_2O_3 catalyst in reducing NO_x emissions in a passive mode hydrocarbon selective catalytic reduction (HC-SCR) was investigated using the exhaust gas from a diesel engine operation on diesel, biodiesel (RME) and low temperature Fischer–Tropsch synthetic diesel (SD). The HC_1:NO_x ratio in the engine exhaust from the combustion of these fuels followed the order: diesel > SD > biodiesel and this order was mirrored in the catalyst activity in reducing NO_x in presence of hydrogen (1000 ppm). Compared to diesel fuel, biodiesel combustion produces a higher amount of NO_x with reduced concentrations of HCs, while both HC and NO_x emissions were reduced in the engine exhaust from the combustion of SD fuel. Although, a higher NO_x reduction in the SCR process was seen in the case of diesel fuelling, due to higher HC_1:NO_x ratio in the engine exhaust compared to biodiesel (RME) and SD, at low exhaust temperatures (190 °C) there was a gradual loss of the catalyst, NO_x reduction activity. The incorporation of EGR within the engine operation, increased significantly HC_1:NO_x ratios in the exhaust, mainly by lowering the NO_x concentration. Under these conditions, which can assumed to represent typical HC_1:NO_x ratios of a modern automotive diesel engine, higher NO_x conversion was seen with SD, followed by diesel and biodiesel. For all the cases examined here the SD fuelling provides the lowest tailpipe NO_x emissions. Hydrogen addition, i.e. at 500, 1000, 1500 and 3000 ppm in the passive mode Ag/Al_2O_3 SCR catalyst needs to be optimized for the different HC_1:NO_x ratios and hydrocarbon species in the exhaust from the combustion of the three fuels.

11/01163 Influence of probe sampling on reacting species measurement in diluted combustion

Lupant, D. *et al. Experimental Thermal and Fluid Science*, 2010, 34, (5), 516–522.

In-flame measurements of temperature and major species are realized with intrusive probes in a laboratory scale furnace working in diluted combustion. The shape and the position of the reaction zone are experimentally identified from the distribution of temperature and carbon monoxide in a particular symmetry plane. For this purpose, two probes were designed: the sampling probe, to measure species content of the gas sample and the suction pyrometer, for the temperature. The first is completely cooled to quench the reaction, but the second is just partly cooled for handling. However, as both probes take gas sample, the species content is available in either case. Consequently the suction pyrometer can be used to measure simultaneously temperature and species, reducing by half the length of the experimental campaign. Comparing species contents on a non-reactive mixture, it has been observed that the spatial averaging is the same with both probes. The perturbation of the flow is assessed thanks to a CFD modelling of the furnace including the probe. Even if it is significant – the differences between the computed values and the measurements are about three to four times the measurement error – the position and the value of the maximum is well captured as well as the opening of the jet. However, the species contents measured within a reactive mixture differ significantly. For a stable regime, the levels and the distribution of CO are similar with both probes, but the gradients at the border of the reaction zone are sharper with the suction pyrometer. For another regime, for which the reaction zone is lifted and less stable, the fields of species are completely different following the probe used. A chemical kinetic modelling has shown that the reaction inside the non-cooled part of the suction pyrometer is promoted when it is placed in particular region. The use of the suction pyrometer as sampling probe inside a reaction zone should therefore be avoided even in diluted combustion. The error made on the fields of species cannot be quantified to be taken into account *a posteriori*, because in certain conditions the results are completely unrealistic.

11/01164 Modelling anhydrous weight loss of wood chips during torrefaction in a pilot kiln

Repellin, V. *et al. Biomass and Bioenergy*, 2010, 34, (5), 602–609.

Beech and spruce chips were torrefied in a batch rotating pilot kiln. For each torrefaction the temperature curve of the moving chips bed was recorded. The anhydrous weight loss (AWL) of each torrefaction was measured. Effect of torrefaction temperature and duration on the AWL was studied. In order to optimize short time torrefaction, models that can estimate the AWL from the chips temperature curve are required. Three phenomenological models were successfully applied. They all gave good correlations between experimental and calculated AWL. These three models can be employed to optimize industrial torrefaction. However, the more complex they are, the more difficult it is to understand their physical meaning. It is thus preferable to use simple model for the industrial control of torrefaction.

11/01165 Monitoring combustion systems using HMM probabilistic reasoning in dynamic flame images

Chen, J. *et al. Applied Energy*, 2010, 87, (7), 2169–2179.

In this paper, a novel method of on-line flame detection in video is proposed. Processing the data generated by an ordinary camera monitoring scene, it aims to early detect the current state of the combustion system and prevent the system from further degradation and occurrence of failure. Due to the dynamic change of the combustion system, the turbulent flame flicker produces images with different spatial and high temporal resolutions. The proposed method consists of hidden Markov model (HMM) and multiway principal component analysis (MPCA). MPCA is used to extract the cross-correlation among spatial relationships in the low dimensional space while HMM constructs the temporal behaviour of the sequential observation. Although the prior process knowledge may not be available in the operation processes, the probability distribution of the normal status can be trained by the images collected from the normal operation processes. Subsequently, monitoring of a new observed image is achieved by a recursive Viterbi algorithm which can find the transition state sequence from series of observed image data. The proposed method, like the philosophy of traditional statistical process control, can generate simple probability monitoring charts to track the progress of the current transition state sequence and monitor the occurrence of the observable upsets. The advantages of the proposed method, data from the monitoring practice in the real combustion systems, are presented to help readers delve into the matter.

11/01166 Numerical simulation of the flow streams behavior in a self-regenerative crucible furnace

Cadavid, F. *et al. Applied Thermal Engineering*, 2010, 30, (8–9), 826–832.

This paper presents a three-dimensional numerical simulation with experimental validation of a gas-fired self-regenerative crucible furnace. Turbulence, radiation and chemical reactions are simulated using the software Gambit V2 and Fluent V6.2. Different combustion models are used to assess their effects on the numerical results. Aerodynamics, temperature fields, species profiles and emissions are compared with the experimental data. The results indicate that k–ε re-normalization group (RNG) model predicts the formation of two concentric swirls: the first one elevating up to the top of the furnace and the second one going down and reaching the outlet. In addition, it was found that is important to inject the fuel using certain vertical inclination of the nozzle in order to obtain a longer and flater flame. Finally, the use of PDF mixture fraction model for combustion causes overprediction of both temperature and CO, while the finite rate/eddy dissipation model is rougher for temperature and species prediction.

11/01167 Particle dynamics simulation of nanoparticle formation in a flame reactor using a polydispersed submicron-sized solid precursor

Widiyastuti, W. *et al. Chemical Engineering Journal*, 2010, 158, (2), 362–367.

Formation of nanoparticles from polydispersed, non-spherical submicron-sized particles via a gas-phase route in a flame reactor was investigated using tungsten oxide particles as a model material. Nanoparticles were formed by the evaporation of non-spherical powder, followed by nucleation, coagulation and surface condensation. The effects of both the flame temperature profile and the carrier gas flow rate on particles formation were studied numerically, and the results were validated by experimental data. The simulation was initiated by the use of computational fluid dynamics to obtain the temperature distribution in the flame reactor. Then, evaporation of the feed material was modelled, taking into account both the polydispersity and the shape of the non-spherical particles. A nodal method was selected to solve the general dynamics equation, which included nucleation, coagulation, and surface condensation terms, for the prediction of particle dynamics. Results of the simulation were consistent with the experimental data, indicating that the selected model adequately predicts the final particle size distribution.

11/01168 PDA research on a novel pulverized coal combustion technology for a large utility boiler

Fan, W. *et al. Energy*, 2010, 35, (5), 2141–2148.

In this paper, a new technology for a tangential firing pulverized coal boiler, high efficiency and low NO_x combustion technology with multiple air-staged and a large-angle counter flow fuel-rich jet (ACCT for short) is proposed. To verify the characteristics of this technology, experiments of two combustion technologies, ACCT and CFS-1 (Concentric Firing System-1), are carried out under a cold model of a 1025 t/h tangential firing boiler with a PDA (particle dynamics anemometer). The distributions of velocity, particle concentration, particle diameters and the particle volume flux of primary air and secondary air are obtained. The results show that the fuel-rich primary air of ACCT can go deeper into the furnace and mix with the main flow better, which means that the counter flow of fuel-rich jets in ACCT can realize stable combustion, low NO_x emission and slagging prevention.

11/01169 Properties of char particles obtained under O_2/N_2 and O_2/CO_2 combustion environments

Li, Q. *et al. Chemical Engineering and Processing: Process Intensification*, 2010, 49, (5), 449–459.

Pulverized coal combustion in O_2/N_2 and O_2/CO_2 environments was investigated with a drop tube furnace. Results present that the reaction rate and burn-out degree of O_2/CO_2 chars (obtained in O_2/CO_2 environments) are lower than that of O_2/N_2 chars (obtained in O_2/N_2 environments) under the same experimental condition. It indicates that a higher O_2 concentration in O_2/CO_2 environment is needed to achieve the similar combustion characteristic to that in O_2/N_2 environment. The main differences between O_2/N_2 and O_2/CO_2 chars rely on the pore structure determined by N_2 adsorption and chemical structure measured by FT-IR. For O_2/CO_2 char, the surface is thick and the pores are compact which contribute to the fragmentation reduction of particles burning in O_2/CO_2 environment. The organic functional group elimination rate from the surface of O_2/CO_2 chars is slower or delayed. The present research results might have important implications for further understanding the intrinsic kinetics of pulverized coal combustion in O_2/CO_2 environment.

11/01170 Small scale porous medium combustion system for heat production in households

Avdic, F. *et al. Applied Energy*, 2010, 87, (7), 2148–2155.

For heating purposes in modern households, gas burners are normally applied due to their simplicity, low cost and easy handling. On the other hand, practical experience showed that conventional, open flame gas burners compared to porous medium systems have low dynamic range, i.e. low power modulation capability and, additionally, higher production of pollutants such as carbon monoxide (CO) and nitrogen oxides (NO_x). This is especially notable when the burner operates at low thermal power regimes. In order to avoid the above-mentioned difficulties and disadvantages of conventional burners, new porous medium gas burner system with maximum thermal output of 8 kW has been developed. The objective of the presented work is focused on better understanding and enabling further developing of porous medium burners (PMBs) for household heating systems. The aim of the work is also to develop a compact and highly efficient combined heating system based on the 8 kW gas PMB coupled with a new heat exchanger incorporated into an electro-fossil fuel system considering space and domestic water heating in one-family house. The final result was the heating system with modulation of the thermal power up to approximately 1:8 and low emissions of CO and NO_x.

11/01171 Structures and burning velocity of biomass derived gas flames

Liu, C. *et al. International Journal of Hydrogen Energy*, 2010, 35, (2), 542–555.

Biomass derived gases produced via gasification, pyrolysis, and fermentation are carbon neutral alternative fuels that can be used in gas turbines, furnaces, and piston engines. To make use of these environmentally friendly but energy density low fuels the combustion characteristics of these fuels have to be fully understood. In this study the structure and laminar burning velocity of biomass derived gas flames are investigated using detailed chemical kinetic simulations. The studied gaseous fuels are the air-blown gasification gas, co-firing of gasification gas with methane, pyrolysis gases, landfill gases, and syngas, a mixture of carbon monoxide and hydrogen. The simulated burning velocities of reference fuel mixtures using two widely used chemical kinetic mechanisms, GRI Mech 3.0 and the San Diego mechanism, are compared with the experimental data to explore the uncertainties and scattering of the simulation data. The different chemical kinetic mechanisms are shown to give a reasonable agreement with each other and with experimental data, with a discrepancy within 7% over most of the conditions. The results show that the structures of typical landfill gas flames and co-firing of methane/gasification gas flames share essential similarity with methane flames. The reaction zones of these flames consist of a thin inner layer and a relatively thick CO/H_2 oxidation layer. In the inner layer hydrocarbon fuel (methane) is converted through chain reactions to intermediates such as CH_3, CH_2O, CO, H_2, etc. The structures of gasification gas flames, pyrolysis gas flames, syngas flames share similarity with the oxidization layer of the methane/air flames. Overall, the chemical reactions of all biomass derived gas flames occur in thin zones of the order of less than 1 mm. The thickness of all BDG gas flames is inversely proportional to their respective laminar burning velocity. The laminar burning velocities of landfill gases are found to increase linearly with the mole fraction of methane in the mixtures, whereas for gasification gas, syngas and pyrolysis gas where hydrogen is present, the laminar burning velocities scale linearly with the mole fraction of hydrogen.

11/01172 Study of the influence of vane angle on flow, gas species, temperature, and char burnout in a 200 MW_e lignite-fired boiler

Jing, J. *et al. Fuel*, 2010, 89, (8), 1973–1984.

Various operational parameters of a 200-MW_e, wall-fired, lignite utility boiler under various outer secondary air vane angles were measured. The parameters measured were gas temperature, gas species concentrations, char burnout, and component release rates (C, H and N). Cold air experiments of a single burner were conducted in the laboratory. A double swirl flow pulverized-coal burner has a single ring recirculation zone that forms in the secondary air region in the burner. By decreasing vane angles, maximum values of radial velocity, tangential velocity and turbulence intensity all increase. Moreover, swirl intensity of air flow and recirculation zone size increase. Concomitantly, in the central region of the burner, decreasing the vane angles of outer secondary air increases gas temperatures, CO concentrations, char burnout and component release rates of C, H and N, while O_2 and NO_x concentrations decrease, and an early ignition of pulverized-coal occurs. Meanwhile, in the secondary air region of the burner, conditions are similar except that NO_x mean concentrations are reversed showing instead an increase. In the side wall region, gas temperatures increase, O_2 and NO_x concentrations decrease, but CO concentrations vary only slightly.

11/01173 Study on ash deposition under oxyfuel combustion of coal/biomass blends

Fryda, L. *et al. Fuel*, 2010, 89, (8), 1889–1902.

Combustion in an O_2/CO_2 mixture (oxyfuel) has been recognized as a promising technology for CO_2 capture as it produces a high CO_2 concentration flue gas. Furthermore, biofuels in general contribute to CO_2 reduction in comparison with fossil fuels as they are considered CO_2 neutral. Ash formation and deposition (surface fouling) behaviour of coal/biomass blends under O_2/CO_2 combustion conditions is still not

extensively studied. Aim of this work is the comparative study of ash formation and deposition of selected coal/biomass blends under oxyfuel and air conditions in a lab-scale pulverized coal combustor (drop tube). The fuels used were Russian and South African coals and their blends with Shea meal (cocoa). A horizontal deposition probe, equipped with thermocouples and heat transfer sensors for on line data acquisition, was placed at a fixed distance from the burner in order to simulate the ash deposition on heat transfer surfaces (e.g. water or steam tubes). Furthermore, a cascade impactor (staged filter) was used to obtain size distributed ash samples including the submicron range at the reactor exit. The deposition ratio and propensity measured for the various experimental conditions were higher in all oxyfuel cases. The SEM/EDS and ICP analyses of the deposit and cascade impactor ash samples indicate K interactions with the alumina silicates and to a smaller extend with Cl, which was all released in the gas phase, in both the oxyfuel and air combustion samples. Sulfur was depleted in both the air or oxyfuel ash deposits. S and K enrichment was detected in the fine ash stages, slightly increased under air combustion conditions. Chemical equilibrium calculations were carried out to facilitate the interpretation of the measured data; the results indicate that temperature dependence and fuels/blends ash composition are the major factors affecting gaseous compounds and ash composition rather than the combustion environment, which seems to affect the fine ash (submicron) ash composition, and the ash deposition mechanisms.

11/01174 The thermal protection of a specific experimental instrument for monitoring of combustion conditions on the grate of municipal solid waste incinerators

Martinec, J. *et al. Applied Thermal Engineering*, 2010, 30, (8–9), 1022–1028.

The thermal protection of the specific experimental instrument for monitoring of combustion conditions on the grate of municipal solid waste incinerators (MSWI) represents a very important part of the assembled measuring system. The inner part of the instrument with control electronics and diverse sensors (temperature and flue gas concentration measurements) requires sufficient thermal protection against the high temperature environment of the combustion process with a surrounding temperature higher than 1200 °C. The influence of the high temperature environment is limited, but not fully eliminated, by thermal protection. The thermal protection is applied in two different ways. The standard thermal insulation with low thermal conductivity represents passive protection. The optimal thickness of the insulation itself partially defines the heat flux to the central part of the measuring system and its impacts upon increase of the inner temperature. The second type of protection, in an active mode, in addition to low conductivity, also provides heat storage. The full-scale thermal protection is designed by means of computer calculations with boundary and initial conditions or laboratory measurements within a similar environment to that on the grate of the MSWI. An additional aim of the sufficient thermal protection development is also to minimize the final size of the experimental instrument. The experimental trials have approved the functionality of the measuring instrument in high temperatures by keeping the inner temperature at the very low level.

11/01175 Thermochemical heat release of laminar stagnation flames of fuel and oxygen

Cremers, M. F. G. *et al. International Journal of Heat and Mass Transfer*, 2010, 53, (5–6), 952–961.

Heat transfer is a complex phenomenon that can involve conduction, convection, radiation, condensation, and boiling. In the case of heat transfer by flames produced by pure oxygen or oxygen enriched air combustion, a mechanism called thermochemical heat release (TCHR) can be held responsible for up to 60% of the total heat transfer rate. In these very hot flames chemical equilibrium is reached before full conversion into products is achieved. TCHR is the result of recombination reactions in the thermal boundary layer. In this paper a method is described for the numerical calculation of the effect of TCHR which can be applied to model TCHR for fuels of an almost arbitrarily complex composition. In this method the flame chemistry is decoupled from the chemistry in the thermal boundary layer. An equilibrium calculation is used to determine the chemical composition after the flame. This mixture is then used as input for the stagnation layer calculations, for which a simple CH_4 mechanism suffices. It is shown under which conditions this method can be applied, the effect of strain rate is studied, and the method is demonstrated by calculating a TCHR multiplication factor for a number of different fuels. A polynomial fit for the TCHR-factor is presented as function of C/H-ratio, equivalence ratio, equivalent temperature of a reference mixture and stagnation plane temperature. The fit gives accurate results for the TCHR contribution to the total heat transfer for most fuels. Finally, the importance of hydrogen recombination chemistry on the TCHR is indicated.

11/01176 Validation of a FBC model for co-firing of hazelnut shell with lignite against experimental data

Kulah, G. *Experimental Thermal and Fluid Science*, 2010, 34, (5), 646–655.

Performance of a comprehensive system model extended for modelling of co-firing of lignite and biomass was assessed by applying it to METU 0.3 MW_t atmospheric bubbling fluidized bed combustor co-firing lignite with hazelnut shell and validating its predictions against on-line temperature and concentration measurements of O_2, CO_2, CO, SO_2 and NO along the same test rig fired with lignite only, lignite with limestone addition and lignite with biomass and limestone addition. The system model accounts for hydrodynamics; volatiles release and combustion, char combustion, particle size distribution for lignite and biomass; entrainment; elutriation; sulfur retention and NO formation and reduction, and is based on conservation equations for energy and chemical species. Special attention was paid to different devolatilization characteristics of lignite and biomass. A volatiles release model based on a particle movement model and a devolatilization kinetic model were incorporated into the system model separately for both fuels. Kinetic parameters for devolatilization were determined via thermogravimetric analysis. Predicted and measured temperatures and concentrations of gaseous species along the combustor were found to be in good agreement. Introduction of biomass to lignite was found to decrease SO_2 emissions but did not affect NO emissions significantly. The system model proposed in this study proves to be a useful tool in qualitatively and quantitatively simulating the processes taking place in a bubbling fluidized bed combustor burning lignite with biomass.

11/01177 Wavelength and temperature dependences of the absorption and scattering cross sections of soot

Michelsen, H. A. *et al. Carbon*, 2010, 48, (8), 2175–2191.

This paper considers the wavelength and temperature dependence of the absorption and scattering cross-sections of mature soot in an ethylene flame from laser-induced incandescence (LII) and transmittance measurements at 532 and 1064 nm. The LII measurements indicate that the emissivity of soot in a flame deviates from the expected $1/\lambda$ dependence. Combining the LII results with transmittance measurements yields single-scattering albedos of 0.058–0.077 at 1064 nm and 0.22–0.29 at 532 nm and values of $F(m)/E(m)$ of 2.2–2.9 at 532 nm and 2.4–3.3 at 1064 nm. These values confirm that scattering must be taken into account when interpreting extinction data at these wavelengths. The results also indicate increases in the absorption cross-section and decreases in the scattering cross-section with increasing fluence at low fluences. The increase in absorption cross-section is consistent with increases in primary particle size with increasing particle temperature during laser heating. The decrease in scattering cross-section could be attributable to an increase in the radius of gyration or a decrease in the fractal dimension of the aggregate with increasing temperature. Alternatively these trends might be the result of changes to the optical properties of the particles with increasing temperature.

Fire safety

11/01178 Economic evaluation of a roll-off trucking system removing forest biomass resulting from shaded fuelbreak treatments

Han, H.-S. *et al. Biomass and Bioenergy*, 2010, 34, (7), 1006–1016.

Shaded fuelbreak treatments involve removal of understory brush and small-diameter trees to reduce fire hazards by disconnecting the continuity of fuels. As a result of these treatments, woody biomass (referred to as slash) is piled throughout the treated stand and later burned. Mechanical removal of slash has not been successfully implemented in many areas due to limited accessibility to sites and the high costs associated with collection and transportation of slash. To address these issues, a roll-off truck paired with a small skid-steer loader was used to collect and transport slash to a centralized processing site where slash was ground as hog fuel for energy production. 'Roll-off truck' refers to a straight frame truck configuration in which a 30.6-m^3 container is rolled onto and off the straight frame truck by means of a truck-mounted winch system. This study was designed to quantify the operational performance and costs of removing slash piles using a roll-off trucking system in mountainous conditions in northern California. The overall cost to collect and haul hand-piled slash was $26.81/tonne with 22% average moisture content or $34.37/bone dry metric ton. The roll-off trucking system should be used primarily for short hauling distances since trucking costs significantly increase with small increases in hauling distance due to slow travelling speeds and low slash weight being hauled. Financial

analysis indicated that contractors can receive high rates of return on their invested capital after accounting for inflation and income taxes, but limited work opportunities are a concern for them.

11/01179 Experimental study on buoyant flow stratification induced by a fire in a horizontal channel
Yang, D. *et al. Applied Thermal Engineering*, 2010, 30, (8–9), 872–878.
Experiments were carried out in a reduced-scale horizontal channel to investigate the fire-induced buoyant flow stratification behaviour, with the effect of the velocity shear between the hot buoyant flow and the cool air flow considered. This shear intensity was controlled and varied by changing the exhaust rate at the ceiling with one of the end of the channel opened. The flow pattern was visualized by the aid of a laser sheet. The horizontal traveling velocity, vertical temperature profile and stratification interface height of the buoyant flow were measured. The stratification pattern was found to fall into three regimes. Buoyancy force and inertia force, as the two factors that dominate the buoyant flow stratification, were correlated through the Froude number and the Richardson number. At Region I ($Ri > 0.9$ or $Fr < 1.2$), the buoyant flow stratification was stable, where a distinct interface existed between the upper smoke layer and the lower air layer. At Region II ($0.3 < Ri < 0.9$ or $1.2 < Fr < 2.4$), the buoyant flow stratification was stable but with interfacial instability. At Range III ($Ri < 0.3$ or $Fr > 2.4$), the buoyant flow stratification becomes unstable, with a strong mixing between the buoyant flow and the air flow and then a thickened smoke layer.

11/01180 Geometric effect of radiative heat exchange in concave structure with application to heating of steel I-sections in fire
Wang, Z.-H. *International Journal of Heat and Mass Transfer*, 2010, 53, (5–6), 997–1003.
In structural fire engineering, it is well-known that the radiative heat exchange in unprotected steel I-section is attenuated due to geometric effect. An analytical approach to formulate the geometric effect by employing view factors is presented in this paper for concave structures in general. In particular, the exact solution is extended to predict the net radiation flux and the temperature evolution for unprotected steel I-sections in fire, which are fully characterized by the I-section aspect (width-to-depth) ratio. The proposed method is validated by comparison to the conventional model in Eurocode 3, as well as to experimental investigations. The method predicts the transient temperature field inside the I-sections with reasonable accuracy, while Eurocode provision yields over-estimations. Besides, the effective emissivity is found to be insensitive to temperature, but rather controlled by the section aspect ratio.

11/01181 Preparation and characterization of flame retardant form-stable phase change materials composed by EPDM, paraffin and nano magnesium hydroxide
Song, G. *et al. Energy*, 2010, 35, (5), 2179–2183.
Paraffin, one of the important thermal energy storage materials, possesses various desirable characteristics (e.g. high heat of fusion, variable phase change temperature, self-nucleating, no phase segregation and low cost), but has low thermal stability and is flammable. In the current study, form-stable phase change materials (PCMs) based on EPDM (supported material), paraffin (dispersed phase change material), nano structured magnesium hydroxide (nano-MH) and red phosphorus (RP) with various compositions were prepared. The self-synthesized nano-MH has a kind of lamellar structure with good dispersal as characterized by X-ray diffraction (XRD) and transmission electron microscopy (TEM). The constructional morphology, thermal stability, latent heat and flame retardant properties of as-prepared form-stable PCM blends were evaluated by using a scanning electron microscope (SEM), thermogravimetric analysis (TGA), a differential scanning calorimeter (DSC) and limited oxygen index (LOI) tester, respectively. The SEM and DSC results show that addition of nano-MH and RP has no apparent negative effect on EPDM/paraffin three dimensional netted structures and latent heat. The TGA curves indicate that inducing the nano-MH into the form-stable PCM blends leads to the reinforcement of thermal stability, increasing the amount of char residuals at 700 °C thereby improving the flame retarding performance.

11/01182 Way finding during fire evacuation; an analysis of unannounced fire drills in a hotel at night
Kobes, M. *et al. Building and Environment*, 2010, 45, (3), 537–548.
Findings in earlier studies on fire evacuation and way-finding suggest that building features have an influence on evacuation behaviour. For example, way-finding is believed to be strongly dependent on the lay-out of the building and less dependent on (escape) route signs. Although some aspects have been investigated, it has not been discussed in great length. In particular, there is little insight into how people find their escape routes, and how this process can be supported with lay-out and design measures. Thus, there is need for more research into the decision-making processes which evacuees go through. This paper presents results of 83 evacuation experiments in a hotel building at night. The main focus of the study is on way-finding during fire evacuation. In the evacuation experiments investigated the possible influence of smoke and low placed exit signs on the human fire response performance. The experiments are carried out with a traditional research method, namely the registration and evaluation of unannounced fire drills. The study is conducted as part of the validation of a new research method that makes use of serious gaming. The results of the study suggest that smoke has influence on the route choice: when no smoke is perceptible the majority of the participants escape via the main exit and when smoke blocks the route towards the main exit, the majority of the participants escape via the fire exit. Furthermore, low placed exit signs appear to have a positive influence on the use of the nearest fire exit. The personal feature of prior knowledge of the surroundings (or type of surroundings) is also found to have a positive influence on the use of the nearest fire exit. Self-assessments and interviews after a fire evacuation are found to be a disputable method for research on human behaviour in fire. A real-time observation of the people's behaviour during evacuation is considered to give more reliable results.

09 PROCESS HEATING, POWER AND INCINERATION

Energy applications in industry

11/01183 A comparative study between linear and sliding mode adaptive controllers for a hot gas generator
Abedi, M. *et al. Applied Thermal Engineering*, 2010, 30, (5), 413–424.
A hot gas generator is a compact heat exchanger that produces high temperature or enthalpy gases. This paper presents two methods for controlling the system. The first one is an adaptive sliding mode controller (ASMC) that is a Lyapunov based method and proposed to confront the dynamic modelling deficiencies and system uncertainties. The second one is a linear adaptive controller (LAC) that gives a new attractive ability to the system, which can track a complicated requested path. Each of the presented controllers has some capabilities that may be preferred to other. The main preference of the LAC with respect to the ASMC is the tracking of the complicated paths. On the other hand, the ASMC has the better performance in the presence of the external dynamic noises. Both controllers have an acceptable reaction for the step excitation and also have a good robustness in collation of the air flow rate perturbation and internal noises. It was also shown that the LAC had a good robustness with respect to the identification mechanism singularities.

11/01184 A honey bee foraging approach for optimal location of a biomass power plant
Vera, D. *et al. Applied Energy*, 2010, 87, (7), 2119–2127.
Over eight million hectares of olive trees are cultivated worldwide, especially in Mediterranean countries, where more than 97% of the world's olive oil is produced. The three major olive oil producers are Spain, Italy, and Greece. Olive tree pruning residues are an autochthonous and important renewable source that, in most of cases, farmers burn through an uncontrolled manner. Besides, industrial uses have not yet been developed. The aim of this paper consists of a new calculation tool based on particles swarm (binary honey bee foraging, BHBF). Effectively, this approach will make possible to determine the optimal location, biomass supply area and power plant size that offer the best profitability for investor. Moreover, it prevents the accurate method (not feasible from computational viewpoint). In this work, profitability index (PI) is set as the fitness function for the BHBF approach. Results are compared with other evolutionary optimization algorithms such as binary particle swarm optimization (BPSO), and genetic algorithms (GA). All the experiments have shown that the optimal plant size is 2 MW, $PI = 3.3122$, the best location corresponds to coordinate: $X = 49$, $Y = 97$ and biomass supply area is 161.33 km^2. The simulation times have been reduced to the ninth of time than the greedy (accurate) solution. Matlab® is used to run all simulations.

11/01185 A thermal energy storage process for large scale electric applications
Desrues, T. *et al. Applied Thermal Engineering*, 2010, 30, (5), 425–432.

A new type of thermal energy storage process for large-scale electric applications is presented, based on a high-temperature heat pump cycle which transforms electrical energy into thermal energy and stores it inside two large regenerators, followed by a thermal engine cycle which transforms the stored thermal energy back into electrical energy. The storage principle is described, and its thermodynamic cycle is analysed, leading to the theoretical efficiency of the storage system. A numerical model is developed, and the results show the feasibility of the process, even with sub-optimal parameters. Finally, key factors for improving the process performances are identified.

11/01186 Bio-oil production from fast pyrolysis of waste furniture sawdust in a fluidized bed

Heo, H. S. *et al. Bioresource Technology*, 2010, 101, (S1), S91-S96-.
The amount of waste furniture generated in Korea was over 2.4 million tons in the past 3 years, which can be used for renewable energy or fuel feedstock production. Fast pyrolysis is available for thermochemical conversion of the waste wood mostly into bio-oil. In this work, fast pyrolysis of waste furniture sawdust was investigated under various reaction conditions (pyrolysis temperature, particle size, feed rate and flow rate of fluidizing medium) in a fluidized-bed reactor. The optimal pyrolysis temperature for increased yields of bio-oil was 450 °C. Excessively smaller or larger feed size negatively affected the production of bio-oil. Higher flow and feeding rates were more effective for the production of bio-oil, but did not greatly affect the bio-oil yields within the tested ranges. The use of product gas as the fluidizing medium had a potential for increased bio-oil yields.

11/01187 CFD analysis of thermodynamic cycles in a pulse tube refrigerator

Chen, L. *et al. Cryogenics*, 2010, 50, (11–12), 743–749.
The objectives of this paper are to study the thermodynamic cycles in an inertance tube pulse tube refrigerator (ITPTR) by means of CFD method. The simulation results show that gas parcels working in different parts of ITPTR undergo different thermodynamic cycles. The net effects of those thermodynamic cycles are pumping heat from the low temperature part to the high temperature part of the system. The simulation results also show that under different frequencies of piston movement, the gas parcels working in the same part of the system will undergo the same type of thermodynamic cycles. The simulated thermal cycles are compared with those thermodynamic analysis results from a reference. Comparisons show that both CFD simulations and theoretical analysis predict the same type of thermal cycles at the same location. However, only CFD simulation can give the quantitative results, while the thermodynamic analysis is still remaining in quality.

11/01188 CFD simulation of hydrodynamics and heat transfer in gas phase ethylene polymerization reactors

Dehnavi, M. A. *et al. International Communications in Heat and Mass Transfer*, 2010, 37, (4), 437–442.
The hydrodynamics and temperature of a two-dimensional gas–solid fluidized bed of gas phase olefin polymerization reactor had been studied. A two-fluid Eulerian computational fluid dynamics (CFD) model with closure relationships according to the kinetic theory of granular flow has been applied in order to simulate the gas–solid flow. Fluidization regime and gas–solid flow pattern were investigated using three different drag models. Model predictions of bed pressure drop were compared with corresponding experimental data reported in the literature to validate the model. The predicted values were in reasonable agreement with the experimental data. The temperature behaviour of fluidized bed with various drag models was investigated. The temperature gradient in the primary section of the bed was much larger than the gradient in other sections and the effect of all drag models on temperature gradient along the bed was approximately similar.

11/01189 Ecological performance optimisation for an open-cycle ICR gas turbine power plant. Part 1 – thermodynamic modelling

Chen, L. G. *et al. Journal of the Energy Institute*, 2010, 83, (4), 235–241.
Considering the flow processes of the working fluid with the pressure drops, a thermodynamic model for open cycle intercooled and regenerated gas turbine power plant is established using finite time thermodynamics. The flow processes of the working fluid with the pressure drops of the working fluid and the size constraints of the real power plant are modelled. There are 19 flow resistances encountered by the working fluid for the cycle model. Five of these, the frictions through the blades, vanes of the compressors and the turbines, are related to the isentropic efficiencies. Three of these, the frictions through the intercooler and the regenerator, are related to the effectiveness of the heat exchangers. The remaining flow resistances are always present because of the changes in the flow cross-section at the compressor inlets and outlets, the intercooler inlet and outlet, the regenerator inlet and outlet, the combustion chamber inlet and outlet, and the turbine inlets and outlets. These resistances which are associated with the flow through various cross-sectional areas are derived as functions of the low-pressure compressor inlet relative pressure drop. The analytical formula about the ecological performance is derived with the 19 pressure drop losses. The numerical examples show that the dimensionless ecological performance reaches its maximum value at the optimal values of the intercooling pressure ratio and the low-pressure compressor inlet relative pressure drop.

11/01190 Ecological performance optimisation for an open-cycle ICR gas turbine power plant. Part 2 – optimisation

Wang, W. H. *et al. Journal of the Energy Institute*, 2010, 83, (4), 242–248.
The ecological performance of an open-cycle intercooled and regenerated gas turbine power plant with pressure drop irreversibilities is optimized based on the model established using finite time thermodynamics in Part 1 of this article by adjusting the mass flow rate (or the distribution of pressure losses along the flow path) and the intercooling pressure ratio. It is shown that there are an optimal air mass flow rate (or the distribution of pressure losses along the flow path) and an intercooling pressure ratio which maximize the ecological performance, and the maximum ecological function has an additional maximum with respect to the compressor total pressure ratio. The effects of the effectiveness of the intercooler and the regenerator on the cycle ecological performance and its corresponding parameters are analysed. When the optimization is performed with the constraints of the plant size, the ecological performance can be maximized again by properly allocating the fixed flow area between the compressor inlet and the power turbine outlet. The numerical examples show the effects of design parameters on the ecological performance and the difference between the maximum ecological performance design and the maximum power design.

11/01191 Effects of energy conservation in major energy-intensive industrial sectors on emissions of polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans in China

Geng, J. *et al. Energy Policy*, 2010, 38, (5), 2346–2356.
China has set an ambitious target of increasing energy efficiency by 20% and reducing pollution discharges by 10% over the period 2006–2010. Promoting advanced technologies and closing outdated facilities are widely recognized as important measures to achieve these targets. These actions can also indirectly decrease release of polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). The objectives of this paper are to identify and quantify reductions of PCDD/F emissions to air due to measures such as phasing out of obsolete facilities in the four most energy-intensive industrial sectors. Reductions in PCDD/F emissions from power generation were estimated to be 7, 33 and 38 g I-TEQ in 2006, 2007 and 2008, respectively. For the cement industry, reductions were estimated to be 680 g I-TEQ between 2007 and 2008, and 740 g I-TEQ between 2009 and 2010. For the iron and steel industry, the reduction was estimated to be 113.3 g I-TEQ over the period 2007–2010, which includes 76.6 g I-TEQ in 2007. For the coke industry, the reduction was estimated to be 68 g I-TEQ in 2007 and 62 g I-TEQ in 2008.

11/01192 Energy loss in electrochemical diaphragm process of chlorine and alkali industry – a collateral effect of the undesirable generation of chlorate

Lima, P. R. *et al. Energy*, 2010, 35, (5), 2174–2178.
Contamination of NaOH with chlorate constitutes a major problem for the chlorine–alkali industry, particularly when electrolytic cells based on the diaphragm process are employed. In this paper, pilot and laboratory cell experiments revealed that chlorate contamination in diaphragm cells also inhibits hydrogen evolution and gives rise to a significant increase in electrical energy consumption. Electrolysis carried out under conditions that simulated the industrial process (current density 240 mA cm^{-2}; temperature 90 °C; brine flux 23 L cm^{-2} h^{-1}) revealed that chlorate formation depends on brine flux and NaOH production. The inhibitory effect of chlorate on the main cathodic reaction was demonstrated in bench cell experiments, with cathodic displacement of the hydrogen evolution reaction by more than 100 mV in the presence of 0.4% chlorate compared with ideal conditions in which chlorate formation was absent. This hydrogen generation overpotential can charge the total electric energy balance in more than 5% of the total value, consisting of a critical loss for this process.

11/01193 Exit blade geometry and part-load performance of small axial flow propeller turbines: an experimental investigation

Singh, P. and Nestmann, F. *Experimental Thermal and Fluid Science*, 2010, 34, (6), 798–811.
A detailed experimental investigation of the effects of exit blade geometry on the part-load performance of low-head, axial flow propeller turbines is presented. Even as these turbines find important

applications in small-scale energy generation using micro-hydro, the relationship between the layout of blade profile, geometry and turbine performance continues to be poorly characterized. The experimental results presented here help understand the relationship between exit tip angle, discharge through the turbine, shaft power, and efficiency. The modification was implemented on two different propeller runners and it was found that the power and efficiency gains from decreasing the exit tip angle could be explained by a theoretical model presented here based on classical theory of turbomachines. In particular, the focus is on the behaviour of internal parameters like the runner loss coefficient, relative flow angle at exit, mean axial flow velocity and net tangential flow velocity. The study concluded that the effects of exit tip modification were significant. The introspective discussion on the theoretical model's limitation and test facility suggests wider and continued experimentation pertaining to the internal parameters like inlet vortex profile and exit swirl profile. It also recommends thorough validation of the model and its improvement so that it can be made capable for accurate characterization of blade geometric effects.

11/01194 Experimental studies and empirical models for the prediction of bed expansion in gas–solid tapered fluidized beds

Sau, D. C. *et al*. *Chemical Engineering and Processing: Process Intensification*, 2010, 49, (4), 418–424.

Studies in the expansion behaviour of tapered fluidized bed systems are important for specifying the height of the bed. Data have been obtained on the expanded heights of tapered fluidized beds and bed expansion ratios for spherical and non-spherical particles have been calculated. Based on dimensional analysis, models have been developed as a function of geometry of tapered bed, static bed height, particle diameter, density of solid and gas and superficial velocity of the fluidizing medium. The data used to derive the models cover a wide range of operating conditions, with varying fluidization velocities. Effects of static bed height, particle diameter, density, tapered angle and superficial gas velocity over minimum fluidization velocity on bed expansion ratios have been investigated experimentally. A comparison has been made between the calculated values of bed expansion ratios using proposed models and the experimental data. It has been seen that calculated values by models agree well with the experimental values. Models have also been compared with literature data of conventional bed and found its applicability at higher gas velocities with good accuracy.

11/01195 Experimental study of the transient adsorption/desorption characteristics of silica gel particles in fluidized bed

Hamed, A. M. *et al*. *Energy*, 2010, 35, (6), 2468–2483.

Transient adsorption/desorption characteristics of spherical particles of silica gel (about 3 mm in diameter) in a fluidized bed have been studied experimentally. To control the humidity of inlet air, a humidifier is designed and fitted in a proper location in the system. The system is well instrumented to measure the inlet and outlet air parameters as well as bed temperatures during the experiments. A simplified analytical model with isothermal adsorption assumption is developed. Transient values of the mass of adsorbed water in the bed, rate of adsorption and water content in silica gel particles are evaluated from the experimental measurements. Experimental values of the volumetric mass transfer coefficient and the dimensionless value of water content in the bed are plotted and compared with values obtained from the analytical model for different operating conditions. Good agreement is found at the first period of adsorption, when the adsorption is nearly isothermal. Successive increase in bed temperature, results in increase in the discrepancy between the results of the analytical model and experimental data. Accordingly, the isothermal model could be applied with reasonable degree of reality for systems with shorter adsorption/desorption cycles. The drop in air humidity is highly affected by its inlet value. It is found that the maximum decrease in air humidity occurs at the beginning of adsorption and the rate of water vapour adsorption increases with the increase in the inlet humidity.

11/01196 Finite time thermodynamic modelling and analysis for irreversible IFGT cycles

Ma, Z. S. and Turan, A. *Journal of the Energy Institute*, 2010, 83, (4), 187–194.

Indirectly or externally fired gas turbines (IFGTs or EFGTs) are interesting technologies under development for small and medium scale combined heat and power supplies in combination with micro gas turbine technologies. The emphasis is primarily on the utilization of the waste heat from the turbine in a recuperative process. The possibility also exists for burning biomass even 'dirty' fuel by employing a high temperature heat exchanger (HTHE) to avoid the combustion gases passing through the turbine. In this paper, the theory of finite time thermodynamics is used in the performance analysis of a class of irreversible closed IFGT cycles coupled to variable temperature heat reservoirs. The analytical formulae for the dimensionless power output and efficiency, as functions of the total pressure ratio, component (HTHE, hot and cold side heat exchangers) effectiveness, compressor and turbine efficiencies and the thermal capacity rates of the working fluid and the heat reservoirs, the pressure recovery coefficient, the heat reservoir inlet temperature ratio, are derived. Analyses are carried out based on the formulation. Indirectly fired gas turbine cycles are most efficient under low compression ratio ranges (2.0–5.0) and fit for low power output circumstances for integration with micro gas turbine technology. Optimal total pressure ratio π_c under maximum power output is always higher than that under maximum cycle thermal efficiency. When either of the heat transfer effectiveness of the hot or the cold side heat exchanger, the pressure recovery coefficient, isentropic efficiencies of the gas turbine and the compressor and the heat reservoir inlet temperature ratio increase, the dimensionless power output, cycle efficiency and their corresponding optimal total pressure ratios increase. It must be noted that the optimal total pressure ratio π_e under the maximum cycle thermal efficiency decreases with increase in heat transfer effectiveness of the HTHE. The model derived can be further used to optimize the operational parameters and forecast performance of practical IFGT configurations and choices.

11/01197 Heat transfer and bubble dynamics in a three-phase inverse fluidized bed

Myre, D. and Macchi, A. *Chemical Engineering and Processing: Process Intensification*, 2010, 49, (5), 523–529.

In this study, surface-to-bed heat transfer experiments were performed to gain insight on heat transfer and hydrodynamics in a three-phase inverse fluidized bed. Air, tap water or 0.5 wt% aqueous ethanol, and polypropylene were, respectively, the gas, liquid and solid phases. The solid loading was varied from 0 to 30 vol%, and the gas and liquid superficial velocities from 2 to 50 mm/s and 0 to 21 mm/s, respectively. Visual observations were associated with measured phase holdups and instantaneous heat transfer coefficients. Larger gas velocities lead to an increase in bubble size due to the transition to the coalesced bubble flow regime. The greater turbulence induced by the larger bubbles increases the average heat transfer coefficient. On the other hand, adding ethanol reduces the heat transfer coefficient. Solid concentrations up to 13 vol% increase the average heat transfer coefficient whereas higher solid concentrations tend to lower it. The distribution of instantaneous heat transfer coefficient peak height is wider at higher gas and liquid velocities while the addition of a surfactant narrows it. Gas holdups and average heat transfer coefficients are both compared with existing correlations, which are then adjusted for a better fit.

11/01198 Hydrodynamic characteristics in an inverse internal-loop airlift-driven fibrous-bed bioreactor

Kilonzo, P. M. *et al*. *Chemical Engineering Science*, 2010, 65, (2), 692–707.

An inverse internal loop airlift-driven fibrous bed bioreactor (ALFBB) was designed by combining the advantages of an internal loop airlift bioreactor and packed bed bioreactor into one column. This bioreactor, with a high degree of design flexibility, is expected to handle genetically engineered cells as well as fragile cells, which are shear-sensitive. The hydrodynamic characteristics of the combined system have been investigated. Woven cotton was set in the downcomer of the I-IL-ALB to represent the fibrous bed packed bed and the outcome results were compared with those of the polyurethane foam (PUF) packed system and the unpacked I-IL-ALB system. The effects of the packing nature, packing height, packing top and bottom clearances, gaps between adjacent fibre surfaces, and superficial gas velocities were investigated. The hydrodynamic output variables included the gas holdup and liquid circulation velocity. Gas holdup for all packed systems continuously increased with increases in packing height, packing top clearance and superficial gas velocity. It was found highest in the downcomer of the cotton packed system than in the PUF counterpart due to the roughness and hydrophilicity of the woven cotton fibrous material. Increased amounts of packing in the I-IL-ALB, whether in the form of cotton or PUF decreased the liquid circulation velocity in the bioreactor because of the increased frictional resistance and tortuosity. The reduction in liquid circulation velocity was significant for large packing with small gaps between fibre surfaces and increased bottom clearances of the cotton-packed system. Empirical models based on packing properties are presented which accurately predict the gas holdup, whereas the energy-based model was proposed to predict liquid circulation velocities. The optimum hydrodynamic conditions were observed with cotton packing.

11/01199 Integration of solar thermal for improved energy efficiency in low-temperature-pinch industrial processes

Atkins, M. J. *et al*. *Energy*, 2010, 35, (5), 1867–1873.

Solar thermal systems have the potential to provide renewable industrial process heat and are especially suited for low pinch temperature processes such as those in the food, beverage, and textile sectors. When correctly integrated within an industrial process, they can provide significant progress towards both increased energy

efficiency and reduction in emissions. However, the integration of renewable solar energy into industrial processes presents a challenge for existing process integration techniques due to the non-continuous nature of the supply. A thorough pinch analysis study of the industrial process, taking in to account non-continuous operating rates, should be performed to evaluate the utility demand profile. Solar collector efficiency data under variable climatic conditions should also be collected for the specific site. A systematic method of combining this information leads to improved design and an optimal operating strategy. This approach has been applied to a New Zealand milk powder plant and benefits of several integration strategies, including mass integration, are investigated. The appropriate placement of the solar heat is analogous to the placement of a hot utility source and an energy penalty will be incurred when the solar thermal system provides heat below the pinch temperature.

11/01200 Modeling calcium dissolution from oil shale ash: Part 1. Ca dissolution during ash washing in a batch reactor
Velts, O. *et al. Fuel Processing Technology*, 2010, 91, (5), 486–490.
Batch dissolution experiments were carried out to investigate Ca leachability from oil shale ashes formed in boilers operating with different combustion technologies. The main characteristics of Ca dissolution equilibrium and dynamics, including Ca internal mass transfer through effective diffusion coefficients inside the ash particle were evaluated. Based on the collected data, models allowing simulation of the Ca dissolution process from oil shale ashes during ash washing in a batch reactor were developed. The models are a set of differential equations that describe the changes in Ca content in the solid and liquid phase of the ash–water suspension.

11/01201 Modeling calcium dissolution from oil shale ash: Part 2. Continuous washing of the ash layer
Velts, O. *et al. Fuel Processing Technology*, 2010, 91, (5), 491–495.
In the present work a possible approach to the utilization of oil shale ash containing free lime in precipitated calcium carbonate (PCC) production is elucidated. This paper investigates the Ca (calcium) dissolution process during continuous washing of pulverized firing (PF) and fluidized bed combustion (FBC) oil shale ash layers in a packed-bed leaching column. The main characteristics of the Ca dissolution process from ash are established. The effect of water flow rate is investigated by conducting leaching experiments of oil shale ashes formed in boilers operating with different combustion technologies. The values of the overall and liquid phase mass transfer coefficients are evaluated based on experiments using the developed ash layer washing model. The model is a set of partial differential equations that describe the changes in Ca content in the stagnant layer of ash and in the water flowing through the ash layer. An example in which the model is applied to environmental assessment and estimation of Ca leaching from industrial oil shale ash fields is provided.

11/01202 Potential for reduction of CO_2 emissions and a low-carbon scenario for the Brazilian industrial sector
Henriques Jr., M. F. *et al. Energy Policy*, 2010, 38, (4), 1946–1961.
This study discusses the potential for reducing CO_2 emissions from energy use by the Brazilian industrial sector in a low-carbon scenario over a horizon until 2030. It evaluates the main mitigation measures, the quantities of this gas avoided and the respective abatement costs. In relation to a benchmark scenario projected for 2030, the reduction of CO_2 emissions estimated here can reach 43%, by adopting energy-efficiency measures, materials recycling and cogeneration, shifting from fossil fuels to renewables or less polluting energy sources and eliminating the use of biomass from deforestation. The set of measures studied here would bring emissions reductions of nearly 1.5 billion tCO_2 over a period of 20 years (2010–2030). This would require huge investments, but the majority of them would have significant economic return and negative abatement costs. However, in many cases there would be low economic attractiveness and higher abatement costs, thus requiring more effective incentives. Brazil is already carrying out various actions toward the mitigation measures proposed here, but there are still substantial barriers to realize this potential. Therefore, a collective effort from both the public and private sectors is needed for the country to achieve this low-carbon scenario.

11/01203 Preliminary estimations of energy and cost for CO_2 recovery by a membrane flash process utilizing waste thermal energy
Okabe, K. *et al. International Journal of Greenhouse Gas Control*, 2010, 4, (4), 597–602.
The membrane flash process utilizing waste thermal energy was developed to achieve an energy-saving technology and to substitute it for a conventional regenerator. The operating conditions of the membrane flash at high temperature were studied. The petroleum refining process and iron manufacturing process were proposed for candidate processes that actually had waste energy sources. The DEA concentration and the flashing pressure had optimum values to improve the performance and reduce the energy consumption for CO_2 recovery. Energy consumptions and costs for CO_2 recovery in the membrane flash and chemical absorption were estimated by a process simulator and discussed under the same conditions. The membrane flash can achieve lower energy capture than the chemical absorption for the above industrial processes. The membrane flash is suitable for the CO_2 emission sources that had high CO_2 concentration independently of the plant scale. The chemical absorption can be applied if the plant scale is large and also the CO_2 concentration is low.

11/01204 Studies of Cd, Pb and Cr distribution characteristics in bottom ash following agglomeration/defluidization in a fluidized bed boiler incinerating artificial waste
Liu, Z.-S. *et al. Fuel Processing Technology*, 2010, 91, (6), 591–599.
This study focused on the effects of agglomeration/defluidization on the Cd, Pb and Cr distribution in bottom ash particles of different sizes. This study incinerated artificial waste, which was a mixture of sawdust, polypropylene, selected metal solutions, and polyethylene. The experimental parameters included Na concentration, addition of Ca and Mg and operating temperature. The results indicated that particle size decreased by attrition and thermal impact in the absence of added Na. When Na was added to the system, this metal reacted with silica sand to form eutectics, which increased particle size. Further addition of Ca and Mg was found to prolong the operating time, with greater amounts of liquid eutectic accumulating, leading to increase particle size. The heavy metal concentrations in coarse and fine particles were greater than those present in particles of intermediate sizes over a range of experimental conditions. As the particle size decreased below 0.59 mm or increased above 0.84 mm, the heavy metal concentrations increased. As Ca and Mg were added, the heavy metal concentrations in particles of all sizes increased relative to those present in identical particles when no metals or only Na were added. Additionally, the ratio of Cd sorption to silica sand decreased with increasing Na concentration, but Cr sorption had the opposite tendency. Therefore, while the addition of Na tended to increase agglomeration, it also increased the tendency for heavy metals to remain in the sand bed of fluidized bed incinerators. Addition of Ca and Mg not only inhibited the agglomeration/defluidization process, resulting in increased operating time, but also enhanced the removal of heavy metals by silica sand, decreasing the concentration of heavy metals in reactor exhaust.

10 SPACE HEATING AND COOLING/HEAT PUMPS

11/01205 Adsorption properties of a natural zeolite–water pair for use in adsorption cooling cycles
Solmuş, I. *et al. Applied Energy*, 2010, 87, (6), 2062–2067.
The equilibrium adsorption capacity of water on a natural zeolite has been experimentally determined at different zeolite temperatures and water vapour pressures for use in an adsorption cooling system. The Dubinin–Astakhov adsorption equilibrium model is fitted to experimental data with an acceptable error limit. Separate correlations are obtained for adsorption and desorption processes as well as a single correlation to model both processes. The isosteric heat of adsorption of water on zeolite has been calculated using the Clausius–Clapeyron equation as a function of adsorption capacity. The cyclic adsorption capacity swing for different condenser, evaporator and adsorbent temperatures is compared with that for the following adsorbent–refrigerant pairs: activated carbon–methanol; silica gel–water; and, zeolite 13X–water. Experimental results show that the maximum adsorption capacity of natural zeolite is nearly 0.12 kg_w/kg_{ad} for zeolite temperatures and water vapour pressures in the range 40–150 °C and 0.87–7.38 kPa.

11/01206 Augmentation of heat transfer performance in coiled flow inverter vis-à-vis conventional heat exchanger
Mandal, M. M. *et al. Chemical Engineering Science*, 2010, 65, (2), 999–1007.
In the present work two studies were carried out to ascertain the performance of coiled flow inverter (CFI) as heat exchanger at pilot plant scale. In the first study, performance of CFI heat exchanger has been compared with conventional heat exchangers, i.e. shell and tube heat exchanger (SHE) and plate-type heat exchanger (PHE) under identical heat transfer area and process conditions. Experiments were conducted with water flowing under laminar flow regime within the flow range of 30–300 kg/h in the tube side of SHE and PHE. Friction factor and Nusselt number calculated from present experimental study in SHE and PHE were compared with the experimental data previously reported for CFI heat exchanger. The number of transfer units

calculated in the present study for CFI was nearly 3.7–7.5 times higher as compared to SHE and 2–2.5 times higher as compared to PHE. In the second part of the study, experiments were performed to investigate the pressure drop and heat transfer of compressed air flowing under turbulent flow condition in CFI heat exchanger at pilot plant scale. Hot air at elevated pressures (10–30 kg/cm^2) in the tube side of CFI heat exchanger with flow range $3 \times 10^4 < N_{Re} < 1.4 \times 10^5$ was cooled by either cooling water or ambient air. The friction factor and Nusselt number values for compressed air flowing in the CFI were also compared with the experimental data reported in the literature for coiled tube at ambient conditions. On the basis of experimental results, new correlations for friction factor and Nusselt number of compressed air flowing under turbulent flow condition in CFI heat exchanger have been developed.

11/01207 Biomass gasification opportunities in a district heating system

Difs, K. *et al. Biomass and Bioenergy*, 2010, 34, (5), 637–651.

This paper evaluates the economic effects and the potential for reduced CO_2 emissions when biomass gasification applications are introduced in a Swedish district heating (DH) system. The gasification applications included in the study deliver heat to the DH network while producing renewable electricity or biofuels. Gasification applications included are: external superheater for steam from waste incineration (waste boost, WB), gas engine CHP (BIGGE), combined cycle CHP (BIGCC) and production of synthetic natural gas (SNG) for use as transportation fuel. Six scenarios are used, employing two time perspectives – short-term and medium-term – and differing in economic input data, investment options and technical system. To evaluate the economic performance an optimization model is used to identify the most profitable alternatives regarding investments and plant operation while meeting the DH demand. This study shows that introducing biomass gasification in the DH system will lead to economic benefits for the DH supplier as well as reduce global CO_2 emissions. Biomass gasification significantly increases the potential for production of high value products (electricity or SNG) in the DH system. However, which form of investment that is most profitable is shown to be highly dependent on the level of policy instruments for biofuels and renewable electricity. Biomass gasification applications can thus be interesting for DH suppliers in the future, and may be a vital measure to reach the 2020 targets for greenhouse gases and renewable energy, given continued technology development and long-term policy instruments.

11/01208 Control strategy and experimental study on a novel defrosting method for air-source heat pump

Liang, C.-H. *et al. Applied Thermal Engineering*, 2010, 30, (8–9), 892–899.

A new defrosting method that aimed at shelving the various disadvantages of the conventional reverse cycle defrosting was proposed in this paper. To guarantee the reliability, a self-organizing control algorithm with self-learning function was introduced based on the cardinal fuzzy control algorithm. Moreover, the control strategy was enacted; the corresponding self-organizing fuzzy control system was developed; the micro controller unit (MCU)-based control unit was accomplished; and the experimental study was conducted to investigate the sample machine of the air-source heat pump system. The results of the experiments showed that the self-organizing control algorithm has good control characteristic and effect. On one hand, the adverse shock from the conventional reverse cycle defrosting to the refrigeration system could be avoided through this proposed method; on the other hand, the 'oil rush' could also be eliminated. Besides, the thermal comfort could be greatly improved since the temperature fluctuation range of the supplied water is narrowed by applying this new method in practice.

11/01209 Design and experimental analysis of a carbon dioxide transcritical chiller for commercial refrigeration

Cecchinato, L. *et al. Applied Energy*, 2010, 87, (6), 2095–2101.

Carbon dioxide is an interesting solution for commercial refrigeration and in perspective for air-conditioning systems. In this paper a newly developed carbon dioxide transcritical air cooled chiller for refrigerating propylene glycol down to −8 °C supply temperature is described. The aim of the project was at optimizing the cycle energy efficiency while assuring reliable operation and simple management of the unit. The carbon dioxide optimal pressure issue is addressed with an innovate system architecture and control logic. Using a flash tanks and two electronic valves, the optimal cycle upper pressure was maintained in transcritical operation mode. The managing of the valves allows the refrigeration machine efficiency improvement when the gas cooler inlet air allows subcritical working conditions. A simulation model of the chiller was developed and its results validated with experimental data. A measurement campaign was carried out, testing the chiller at external temperatures ranging from 18 to 35 °C, the unit energy efficiency ranging from 3.1 to 2.0.

11/01210 Design of an individually controlled system for an optimal thermal microenvironment

Watanabe, S. *et al. Building and Environment*, 2010, 45, (3), 549–558.

An individually controlled microenvironment has the potential to satisfy more occupants in a space compared to a total volume uniform environment typically used at present. The performance of an individually controlled system comprising a convection-heated chair, an under-desk radiant heating panel, a floor radiant heating panel, an under-desk air terminal device supplying cool air, and a desk-mounted personalized ventilation as used and identified by 48 human subjects was studied using a thermal manikin at room temperatures of 20, 22 and 26 °C. At a room air temperature of 20 °C, the maximum whole-body heating effect of the heating chair, the under-desk heating panel, and the floor heating panel corresponded to the effect of a room temperature increase of 5.2, 2.8, and 2.1 °C, respectively. The effect was 5.9 °C for the combination of the three heating options. The higher the room air temperature, the lower the heating effect of each heating option or heating combination. The maximum whole-body cooling effect of the tested system was only −0.8 °C at a room air temperature of 26 °C. The heating and cooling capacity of the individually controlled system were identified. These results, analysed together with results obtained from human-subject experiments, reveal that both the heating and the cooling capacity of the individually controlled system need to be increased in order to satisfy most occupants in practice.

11/01211 Drag reducing surfactants for district heating

Krope, A. and Lipus, L. C. *Applied Thermal Engineering*, 2010, 30, (8–9), 833–838.

An application of specific surfactants in district heating and cooling systems can give notable economical benefits due to a reduction in friction and heat transfer attributed to a formation of an additional viscous sublayer along the pipe walls, buffering the turbulence. A mathematical three-layer model of water velocity profile is composed for the calculation of drag reduction and flow-capacity increase. At a properly chosen surfactant and concentration, the local drag can be reduced up to 80%. A computer simulation and optimization for a selected district heating network model with additive shows 4% saving in total costs because smaller pipes and weaker pumps are required.

11/01212 Effect of louver shading devices on building energy requirements

Palmero-Marrero, A. I. and Oliveira, A. C. *Applied Energy*, 2010, 87, (6), 2040–2049.

External louvres are increasingly used to provide solar protection for building glazed surfaces. In this work, a general study of the effect of louvre shading devices applied to different façades of a building is carried out, for different locations (latitudes). Building energy requirements for a building in the cooling and heating seasons is quantified for different window and louvre areas, under climatic conditions of Mexico (Mexico), Cairo (Egypt), Lisbon (Portugal), Madrid (Spain) and London (UK). Also, operative and indoor temperatures were calculated through simulations using TRNSYS software, whereas the model for the shading geometry study was solved with EES software. Both horizontal and vertical louvre layouts were considered. The results show that the integration of louvre shading devices in the building leads to indoor comfortable thermal conditions and may lead to significant energy savings, by comparison to a building without shading devices.

11/01213 Energetic performances of a refrigerating loop using ice slurry

El Abbassi, I. *et al. Applied Thermal Engineering*, 2010, 30, (8–9), 962–969.

The consideration of environmental constraints in production, transport and distribution of cold energy resulted in reconsidering the practices of installations dimensioning in particular. Their containment led to the development of secondary refrigerants such as ice slurries to store, transport and distribute the cold energy. These heat transfer fluids should have good thermophysical properties, giving high transport capability, high heat transfer ability as well as low pressure drops. The use of ice slurries can lead to lower flow rates and smaller pumping power compared to single phase fluid. The purpose of the presented work is to study the distribution network of indirect cold systems thanks to a model allowing the evaluation of the influence of various parameters on the operating behaviour of the installation. The available domain for the use of secondary heat transfer fluid (whether in their single phase or two phase form) is determined considering the best design from an energetic point of view. Because of the essential role of the fluid distribution between the production site and consumers, the study focuses on pressure drops and pumping power due to the fluid flow in cooling loops. For each investigated case, the minimum consumption power is obtained with the two phases (solid–liquid) heat transfer fluid (ice slurry).

11/01214 Energy simulation and analysis of the heat recovery variable refrigerant flow system in winter

Li, Y. M. and Wu, J. Y. *Energy and Buildings*, 2010, 42, (7), 1093–1099.

Heat recovery variable refrigerant flow (HR-VRF) system can supply cooling and heating for the building simultaneously and make good use of the indoor cooling and heating capacity efficiently. This system has a good energy performance and can meet the emerging requirements of modern buildings. In order to evaluate the energy features of the system, a new energy simulation module is developed and embedded in the dynamic energy simulation program, EnergyPlus. Using the program with the newly developed module, the dynamic energy simulation is performed for a simplified typical commercial building. The indoor thermal comfort of the building in winter and the setting temperature of the system are analysed. Based on the simulation results, the energy characteristics of the system are investigated, and it is indicated that different methods of the temperature control and the percentage of the heat recovery have influence on the relative ratio of the energy saving. If the HR-VRF system adopts the same temperature control method as the heat pump VRF (HP-VRF) system, the HR-VRF system promises 15–17% energy-saving potential, when compared to the HP-VRF system.

11/01215 Evaluation of flow patterns and elongated bubble characteristics during the flow boiling of halocarbon refrigerants in a micro-scale channel

Arcanjo, A. A. *et al. Experimental Thermal and Fluid Science*, 2010, 34, (6), 766–775.

In the present study, quasi-diabatic two-phase flow pattern visualizations and measurements of elongated bubble velocity, frequency and length were performed. The tests were run for R134a and R245fa evaporating in a stainless steel tube with diameter of 2.32 mm, mass velocities ranging from 50 to 600 kg/m^{2}s and saturation temperatures of 22 °C, 31 °C and 41 °C. The tube was heated by applying a direct DC current to its surface. Images from a high-speed video-camera (8000 frames/s) obtained through a transparent tube just downstream the heated sections were used to identify the following flow patterns: bubbly, elongated bubbles, churn and annular flows. The visualized flow patterns were compared against published predictions. From this comparison it was found that the methods predicted relatively well the present database. Additionally, elongated bubble velocities, frequencies and lengths were determined based on the analysis of high-speed videos. Results suggested that the elongated bubble velocity depends on mass velocity, vapour quality and saturation temperature. The bubble velocity increases with increasing mass velocity and vapour quality and decreases with increasing saturation temperature. Additionally, bubble velocity was correlated as linear functions of the two-phase superficial velocity.

11/01216 Experimental study of gas engine driven air to water heat pump in cooling mode

Elgendy, E. and Schmidt, J. *Energy*, 2010, 35, (6), 2461–2467.

Nowadays a sustainable development for more efficient use of energy and protection of the environment is of increasing importance. Gas engine heat pumps represent one of the most practicable solutions which offer high energy efficiency and environmentally friendly for heating and cooling applications. In this paper, the performance characteristics of gas engine driven heat pump used in water cooling were investigated experimentally without engine heat recovery. The effects of several important factors (evaporator water inlet temperature, evaporator water volume flow rate, ambient air temperature, and engine speed) on the performance of gas engine driven heat pump were studied in a wide range of operating conditions. The results showed that primary energy ratio of the system increased by 22.5% as evaporator water inlet temperature increased from 13 to 24 °C. On the other hand, varying of engine speed from 1300 to 1750 rpm led to decrease in system primary energy ratio by 13%. Maximum primary energy ratio has been estimated with a value of two over a wide range of operating conditions.

11/01217 Experimental study of natural convection heat transfer in a microencapsulated phase change material slurry

Diaconu, B. M. *et al. Energy*, 2010, 35, (6), 2688–2693.

A new microencapsulated PCM (phase change material) slurry (MEPCS) at high concentration (45% w/w) was developed based on microencapsulated Rubitherm RT6. Its heat storage and heat transfer characteristics have been experimentally investigated in order to assess its suitability for integration into a low temperature heat storage system for solar air conditioning applications. Differential scanning calorimetry tests have been conducted to evaluate the cold storage capacity and phase change temperature range. An experimental setup was built in order to quantify the natural convection heat transfer occurring from a vertical helically coiled tube immersed in the MEPCS. First, tests were carried out using water in order to obtain natural convection heat transfer correlations and then a comparison was made with the results obtained for the MEPCS. It was found that inside the phase change interval the values of the heat transfer coefficient for the MEPCS were significantly higher than for water, under identical temperature conditions.

11/01218 Heat induced voltage generation in electrochemical cell containing zinc oxide nanoparticles

Mondal, A. *et al. Energy*, 2010, 35, (5), 2160–2163.

The search for alternative energy sources has stimulated interest in several new materials. Using an aqueous suspension of zinc oxide nanoparticles in specially designed electrochemical cells significant voltage (maximum 498.0 mV) and storage capacity (60 h) upon thermal excitation was observed. Voltage increased gradually with increasing temperature. The cells exhibited reasonable energy conversion efficiency (maximum 1.05%). Moreover, increases in efficiency and storage duration were observed with the insertion of a planar lipid membrane (PLM) within the electrochemical cell, since the hydrophobic barrier of the lipid membrane hindered back recombination of the charges produced by thermal excitation. The novelty of the cells lies in the fact that voltage was generated by utilizing the heat energy of solar radiation, as opposed to the light quanta of the solar influx used in conventional photovoltaic cells.

11/01219 Heat transfer and fluid dynamics of air–water two-phase flow in micro-channels

Kaji, M. *et al. Experimental Thermal and Fluid Science*, 2010, 34, (4), 446–453.

Heat transfer, pressure drop, and void fraction were simultaneously measured for upward heated air–water non-boiling two-phase flow in 0.51 mm ID tube to investigate thermo–hydro dynamic characteristics of two-phase flow in micro-channels. At low liquid superficial velocity j_l frictional pressure drop agreed with Mishima–Hibiki's correlation, whereas agreed with Chisholm–Laird's correlation at relatively high j_l. Void fraction was lower than the homogeneous model and conventional empirical correlations. To interpret the decrease of void fraction with decrease of tube diameter, a relation among the void fraction, pressure gradient and tube diameter was derived. Heat transfer coefficient fairly agreed with the data for 1.03 and 2.01 mm ID tubes when j_l was relatively high. But it became lower than that for larger diameter tubes when j_l was low. Analogy between heat transfer and frictional pressure drop was proved to hold roughly for the two-phase flow in micro-channel. But satisfactory relation was not obtained under the condition of low liquid superficial velocity.

11/01220 Heat transfer and pressure drop during HFC refrigerant saturated vapour condensation inside a brazed plate heat exchanger

Longo, G. A. *International Journal of Heat and Mass Transfer*, 2010, 53, (5–6), 1079–1087.

This paper presents the heat transfer coefficients and the pressure drop measured during HFC refrigerants 236fa, 134a and 410A saturated vapour condensation inside a brazed plate heat exchanger: the effects of saturation temperature (pressure), refrigerant mass flux and fluid properties are investigated. The heat transfer coefficients show weak sensitivity to saturation temperature (pressure) and great sensitivity to refrigerant mass flux and fluid properties. A transition point between gravity controlled and forced convection condensation has been found for a refrigerant mass flux around 20 kg/m^{2}s that corresponds to an equivalent Reynolds number around 1600–1700. At low refrigerant mass flux ($G_r < 20$ kg/m^{2}s) the heat transfer coefficients are not dependent on mass flux and are well predicted by the Nusselt analysis for vertical surface: the condensation process is gravity controlled. For higher refrigerant mass flux ($G_r > 20$ kg/m^{2}s) the heat transfer coefficients depend on mass flux and are well predicted: forced convection condensation occurs. In the forced convection condensation region the heat transfer coefficients show a 25–30% increase for a doubling of the refrigerant mass flux. The frictional pressure drop shows a linear dependence on the kinetic energy per unit volume of the refrigerant flow and therefore a quadratic dependence on mass flux. HFC-410A shows heat transfer coefficients similar to HFC-134a and 10% higher than HFC-236fa together with frictional pressure drops 40–50% lower than HFC-134a and 50–60% lower than HFC-236fa.

11/01221 Heat-transfer characteristics of climbing film evaporation in a vertical tube

Yang, L. *et al. Experimental Thermal and Fluid Science*, 2010, 34, (6), 753–759.

Heat-transfer characteristics of climbing film evaporation were experimentally investigated on a vertical climbing film evaporator heated by tube-outside hot water. The experimental setup was designed for determining the effect of the height of feed water inside a vertical tube and the range of temperature difference on local heat transfer coefficient inside a vertical tube (h_i). In this setup, the height of feed water was successfully controlled and the polypropylene shell effectively impedes the heat loss to the ground. The results indicated that a

reduction in the height of feed water contributed to a significant increase in h_i if no dry patches around the wall of the heated tube appeared inside the tube. The height ratio of feed water $R_h = 0.3$ was proposed as the optimal one as dry patches destroyed the continuous climbing film when R_h is under 0.3. It was found that the minimum temperature difference driving climbing film evaporation is suggested as 5 °C due to a sharp reduction in h_i for temperature difference below 5 °C. The experiment also showed that h_i increased with an increase in temperature difference, which proved the superiority of climbing film evaporation in utilizing low-grade surplus heating source due to its wide range of driving temperature difference. The experimental results were compared with the previous literature and demonstrated a satisfactory agreement.

11/01222 Indoor thermal conditions and thermal comfort in air-conditioned domestic buildings in the dry-desert climate of Kuwait

Al-ajmi, F. F. and Loveday, D. L. *Building and Environment*, 2010, 45, (3), 704–710.

The summer season in the state of Kuwait is long with a mean daily maximum temperature of 45 °C. Domestic air conditioning is generally deployed from the beginning of April to the end of October. This accounts for around 75% of Kuwaiti electrical power consumption. In terms of energy conservation, increasing the thermostat temperature by 1 °C could save about 10% of space cooling energy. However, knowledge of indoor domestic temperatures and thermal comfort sensations is important to aid future advice formulation and policy-making related to domestic energy consumption. A field study was therefore conducted during the summers of 2006 and 2007 to investigate the indoor climate and occupants' thermal comfort in 25 air-conditioned domestic buildings in Kuwait. The paper presents statistical data about the indoor environmental conditions in Kuwait domestic residences, together with an analysis of domestic-occupant thermal comfort sensations. With respect to the latter, a total of 111 participants provided 111 sets of physical measurements together with subjective information via questionnaires that were used to collect the data. By using linear regression analysis of responses on the ASHRAE-seven-point thermal sensation scale, the neutral operative temperatures based on actual mean vote and predicted mean vote were found to be 25.2 and 23.3 °C, respectively, in the summer season. Findings from this study provide information about the indoor domestic thermal environment in Kuwait, together with occupant thermal comfort sensations. This knowledge can contribute towards the development of future energy-related design codes for Kuwait.

11/01223 Introducing a novel integrated NGL recovery process configuration (with a self-refrigeration system (open–closed cycle)) with minimum energy requirement

Mehrpooya, M. *et al. Chemical Engineering and Processing: Process Intensification*, 2010, 49, (4), 376–388.

In this study a novel process configuration for recovery of hydrocarbon liquids from natural gas is proposed. The required refrigeration in this configuration is obtained by a self-refrigeration system (open–closed cycle). High performance of the multi-stream heat exchangers, high recovery levels of the hydrocarbon liquids and low required compression power (in the internal refrigeration section) are three of most important characteristic of the proposed configuration. The effects of the mixed self-refrigerant flow rate and pressure on the performance of the process are discussed. Various values for feed composition are tested and the results show that the process can work efficiently with different feeds. In order to analyse the need of external refrigeration by a close or open cycle that is related to the composition of the inlet gas, a configuration with external refrigeration is designed the manner that it is similar with the purposed configuration in the separation section.

11/01224 Mixing and heat conduction in rotating tumblers

Figueroa, I. *et al. Chemical Engineering Science*, 2010, 65, (2), 1045–1054.

Slow granular flows play an important role in industries ranging from food to pharmaceuticals to ceramics. This subject has received much attention in recent literature; however, heat transfer in even the simplest particle flows is poorly understood. Heat transfer depends on the flow of granular materials: the bed conductivity is a function of the (changing) micro-structure; heat redistribution also depends on particle mixing/segregation. In this work, a multi-scale, multi-physics modelling technique, thermal particle dynamics, is used to examine the interplay between transient heat transfer and particle mixing in rotating tumblers. The effect of the mixing rate on the heating rate of the granular material was studied by changing the tumbler cross-sectional shape and operation parameters–rotation rate and tumbler filling level. The Péclet number was used in the granular bed to determine the dominant heating mechanism–conduction or convection–and to predict conditions that favour more rapid flow of thermal energy in the granular bed. The rate of heat transport is characterized using the Nusselt number and a fluids-inspired relationship correlating this quantity with the Péclet values is attempted. Finally, a continuum model is used to study the relationship between the mixing patterns and temperature contours.

11/01225 On heat conduction in a semi-infinite laminated layer. Comparative results for two approaches

Matysiak, S. J. and Perkowski, D. M. *International Communications in Heat and Mass Transfer*, 2010, 37, (4), 343–349.

The paper deals with the heat conduction in a semi-infinite laminated layer. The non-homogeneous body is assumed to be composed of periodically repeated two-layered laminae. The boundary perpendicular to the layering is subjected to the acting of normal heat flux with parabolic distribution. The free exchange of heat with the surroundings is assumed on the remaining parts of the boundary. The problem is solved by using two approaches: (1) the formulation basing on the classical model of heat conduction with the continuity conditions on interfaces, and (2) the homogenized model with microlocal parameters. The results obtained on both ways are compared and some adequate conclusions connected with the possibilities of applications of the homogenized model with microlocal parameters are presented.

11/01226 On the constant wall temperature boundary condition in internal convection heat transfer studies including viscous dissipation

Aydin, O. and Avci, M. *International Communications in Heat and Mass Transfer*, 2010, 37, (5), 535–539.

In this study, viscous heating effect on convective flow in an unheated adiabatic duct is studied analytically and numerically. Two different geometries are considered: circular duct and plane duct between two parallel plates. Two new parameters are defined for internal convection studies: adiabatic wall temperature and adiabatic bulk temperature. Variations of these two parameters with varying intensity of viscous dissipation effect are determined. In view of the results obtained, usage of the constant wall temperature thermal boundary condition when viscous dissipation is included is discussed and questioned.

11/01227 Optimization of solar adsorption refrigeration system using experimental and statistical techniques

Abu Hamdeh, N. H. and Al-Muhtaseb, M. A. *Energy Conversion and Management*, 2010, 51, (8), 1610–1615.

This paper presents the design of new prototype of a solar adsorption refrigeration units with certain specifications and requirements to be used as an air conditioning and refrigeration unit suitable to be used in remote areas. The new device uses activated carbon (used as adsorbents) with methanol (as adsorbate) forming an adsorbent–adsorbate pairs. Experimental data with statistical technique are used in this paper to get the optimum design parameters of the solar adsorption refrigeration system with an acceptable result of coefficient of performance (COP) and cooling production. The minimum temperature obtained for the refrigerator was 9 °C while the ambient temperature was 26 °C. The effective refrigeration started at 21:10 and the temperature decreased gradually until it reached 9 °C at 01:30 next day then it increased above the minimum temperature. The gross cycle coefficient of performance, $COP_a = 0.688$ from the thermodynamic calculations.

11/01228 Performance of an auto refrigerant cascade refrigerator operating in liquid refrigerant supply (LRS) mode with different cascade heat exchangers

Nayak, H. G. and Venkatarathnam, G. *Cryogenics*, 2010, 50, (11–12), 720–727.

Auto refrigerant cascade (ARC) refrigerators operating with zeotropic mixtures provide refrigeration at temperatures less than 173 K (−100 °C) using a single compressor. Different authors have suggested different cascade heat exchangers for ARC refrigerators. There is no study in literature that suggests at what temperature ranges one, two or three cascade heat exchangers are necessary. In this paper the performance of an ARC refrigerator operating in the liquid refrigerant supply mode and operating with optimized hydrocarbon mixtures and different cascade heat exchangers is studied. The optimum number of cascade heat exchangers (stages) to be used for different operating temperatures is suggested.

11/01229 Preparation and thermal characterization of expanded graphite/paraffin composite phase change material

Xia, L. *et al. Carbon*, 2010, 48, (9), 2538–2548.

Expanded graphite (EG)/paraffin composite phase change materials (PCMs), with mass fraction of EG varying from 0 to 10 wt%, were prepared and characterized. Polarizing optical microscope investigation showed that compact EG networks formed gradually with increase in the mass fraction of EG. These networks provided thermal conduction paths which enhanced the thermal conductivity of the composite PCMs, e.g. an addition of 10 wt% EG resulting in a more than 10-fold increase in the thermal conductivity compared to that of

pure paraffin. Thermal characterization of the composite PCMs with a differential scanning calorimeter (DSC) revealed the effect of the porous EG on the phase change behaviour of paraffin. The shifts in the phase change temperatures were observed. The maximum deviation of the melting/freezing points of the composite PCMs from that of pure paraffin was 1.2 °C whereas that of the peak melting/freezing temperature was 5.6 °C. The DSC investigation also showed an anomaly in the latent heat of the paraffin in the composite PCMs in that it first increased and then decreased with increase in the EG fraction. Heat storage/retrieval tests of the composite PCMs in a latent thermal energy storage system showed that the heat storage/retrieval durations for EG(10)/paraffin(90) composite were reduced by 48.9% and 66.5%, respectively, compared to pure paraffin, which indicated a great improvement in the heat storage/retrieval rates of the system.

11/01230 Second-law performance of heat exchangers for waste heat recovery

San, J.-Y. *Energy*, 2010, 35, (5), 1936–1945.

Exergy change rate in an ideal gas flow or an incompressible flow can be divided into a thermal exergy change rate and a mechanical exergy loss rate. The mechanical exergy loss rates in the two flows were generalized using a pressure-drop factor. For heat exchangers using in waste heat recovery, the consumed mechanical exergy is usually more valuable than the recovered thermal exergy. A weighing factor was proposed to modify the pressure-drop factor. An exergy recovery index (η_{II}) was defined and it was expressed as a function of effectiveness (ε), ratio of modified heat capacity rates (C^*), hot stream-to-dead-state temperature ratio, cold stream-to-dead-state temperature ratio and modified overall pressure-drop factor. This η_{II}–ε relation can be used to find the η_{II} value of a heat exchanger with any flow arrangement. The η_{II}–Ntu and η_{II}–Ntu_h relations of cross-flow heat exchanger with both fluids unmixed were established respectively. The former provides a minimum Ntu design principle and the latter provides a minimum Ntu_h design principle. A numerical example showed that, at a fixed heat capacity rate of the hot stream, the heat exchanger size yielded by the minimum Ntu_h principle is smaller than that yielded by the minimum Ntu principle.

11/01231 Sustainability aspects of geothermal heat pump operation, with experience from Switzerland

Rybach, L. and Eugster, W. J. *Geothermics*, 2010, 39, (4), 365–369.

Geothermal heat pumps are the key to the utilization of the ubiquitous shallow geothermal resources. Theoretical and experimental studies, performed in Switzerland over several years, have established a solid scientific base of reliable long-term operation of borehole heat exchanger-coupled heat pump systems. Proper design, taking into account local conditions like ground properties and building needs, ensures the sustainability of production from systems with single and multiple borehole heat exchangers. Long-term experience acquired at operational objects confirms the predictions.

11/01232 The role of solid surface structure on dropwise phase change processes

Ojha, M. *et al. International Journal of Heat and Mass Transfer*, 2010, 53, (5–6), 910–922.

This study compared the phase change behaviour of a partially wetting fluid, nonane, on various SiO_2 surfaces that had been modified to alter their roughness at the nanoscale. The authors compared a total of four surfaces: an as-received, smooth surface; a surface roughened by plasma-enhanced chemical vapour deposition (PECVD) of SiO_2; and two surfaces where SiO_2 nanorods had been deposited using glancing angle deposition (GLAD). Scanning electron microscopy (SEM) and atomic force microscopy (AFM) were used to characterize the surfaces. The topography of the rough surface controlled the wetting characteristics of the fluid that in turn, controlled the change-of-phase heat transfer rate. The measured apparent contact angle characterized the wetting property during the phase change process. Surface roughness promoted wetting in this system, but the direction of heat transfer controlled the topographic design required for enhanced performance. A comparison between two nanorod coatings of differing heights shows that the longer nanorod coating (30 nm high) acted somewhat like a porous surface promoting condensation heat transfer while the shorter nanorod coating (10 nm high) was much more effective at promoting evaporative heat transfer. Surface alteration at the scale over which intermolecular forces dominates the fluid-solid interaction provides a convenient means for probing those interactions.

11/01233 The simplicity of fractal-like flow networks for effective heat and mass transport

Pence, D. *Experimental Thermal and Fluid Science*, 2010, 34, (4), 474–486.

A variety of applications using disk-shaped fractal-like flow networks and the status of one and two-dimensional predictive models for these applications are summarized. Applications discussed include single-phase and two-phase heat sinks and heat exchangers, two-phase flow separators, desorbers, and passive micromixers. Advantages of using these fractal-like flow networks versus parallel-flow networks include lower pressure drop, lower maximum wall temperature, inlet plenum symmetry, alternate flow paths, and pressure recovery at the bifurcation. The compact nature of microscale fractal-like branching heat exchangers makes them ideal for modularity. Differences between fractal-like and constructal approaches applied to disk-shaped heat sink designs are highlighted, and the importance of including geometric constraints, including fabrication constraints, in flow network design optimization is discussed. Finally, a simple pencil and paper procedure for designing single-phase heat sinks with fractal-like flow networks based solely on geometric constraints is outlined. Benefit-to-cost ratios resulting from geometric-based designs are compared with those from flow networks determined using multivariable optimization. Results from the two network designs are within 11%.

11/01234 Thermal conductivity of a CuCrZr alloy from 5 K to room temperatures

Hanzelka, P. *et al. Cryogenics*, 2010, 50, (11–12), 737–742.

Thermal conductivity of a CuCrZr alloy containing of 0.71% of Cr and 0.23% of Zr was measured in the temperature interval from 5 to 300 K. A method utilizing the measurement of thermal conductivity integral of a sample was verified and applied. Measurements of thermal conductivity, electrical resistivity at 4.2 and 295 K and of Brinell hardness were performed on solution annealed, precipitation hardened and 'as received' materials. The CuCrZr alloy was found to be applicable where high mechanical properties together with high and stable thermal conductivity are required. The possibility to predict the thermal conductivity of precipitation hardened copper alloys from the electrical properties even if the RRR values are lower than 10 was verified at RRR = 5.

11/01235 Thermal-economic multi-objective optimization of plate fin heat exchanger using genetic algorithm

Sanaye, S. and Hajabdollahi, H. *Applied Energy*, 2010, 87, (6), 1893–1902.

Thermal modelling and optimal design of compact heat exchangers are presented in this paper. *ε–NTU* method was applied to estimate the heat exchanger pressure drop and effectiveness. Fin pitch, fin height, fin offset length, cold stream flow length, no-flow length and hot stream flow length were considered as six design parameters. Fast and elitist non-dominated sorting genetic-algorithm (NSGA-II) was applied to obtain the maximum effectiveness and the minimum total annual cost (sum of investment and operation costs) as two objective functions. The results of optimal designs were a set of multiple optimum solutions, called 'Pareto optimal solutions'. The sensitivity analysis of change in optimum effectiveness and total annual cost with change in design parameters of the plate fin heat exchanger was also performed and the results are reported. As a short cut for choosing the system optimal design parameters the correlations between two objectives and six decision variables with acceptable precision were presented using artificial neural network analysis.

11/01236 Transient numerical and physical modelling of temperature profile evolution in stabilised rammed earth walls

Hall, M. R. and Allinson, D. *Applied Thermal Engineering*, 2010, 30, (5), 433–441.

Three established stabilized rammed earth (SRE) mix types (433, 613, 703) were identified for analysis, in the form of 300-mm thick test walls, by being subjected to different static air temperature and relative humidity differentials. The predictive numerical model outputs from WUFI Pro v4.1 hygrothermal simulations displayed good accuracy when validated against experimental data from physical modelling conducted using test walls in a climatic simulation chamber. The wall temperature profile evolution and resultant steady state gradients were very similar regardless of mix type indicating that the majority of the wall remained relatively dry. Unless liquid water is present, the thermal resistance and heat capacity of these materials does not change sufficiently to make significant differences to temperature profile evolution regardless of soil mix type. Little scope exists to intelligently modify the ability of SRE walls to absorb and store heat energy simply by manipulation of particle size distribution (PSD) and the resultant bulk density/void ratio relationships, under these conditions. Only the outer layers of the walls appear to interact with moisture in the air, and the predicted transient responses indicate that significant potential exists to intelligently modify the ability of SRE walls to absorb, store and release moisture vapour from the surrounding air simply by manipulation of PSD and the resultant bulk density/void ratio relationships.

11/01237 Variable refrigerant flow systems: a review

Aynur, T. N. *Energy and Buildings*, 2010, 42, (7), 1106–1112.

This review study presents a detailed overview of the configurations of the outdoor and indoor units of a multi-split variable refrigerant flow (VRF) system, and its operations, applications, marketing and cost. A detailed review about the experimental and numerical studies associated with the VRF systems is provided. The aim is to put together all the diversified information about the VRF systems in a single source. According to detailed review, it is observed that the compressor frequency and the electronic expansion valve opening should be controlled simultaneously for the control strategies, and it is concluded that VRF system not only consumes less energy than the common air conditioning systems such as variable air volume, fan-coil plus fresh air under the same conditions, but also provides better indoor thermal comfort as long as it is operated in the individual control mode. It is found that even though the main drawback of the VRF system is the high initial cost compared to the common air conditioning systems, due to the energy saving potential of the VRF system, the estimated payback period of the VRF system compared to an air cooled chiller system in a generic commercial building could be about 18 months.

11/01238 Ventilation performance prediction for buildings: model assessment
Chen, Q. *et al. Building and Environment*, 2010, 45, (2), 295–303.
Designing ventilation systems for buildings requires a suitable tool to assess the system performance. This investigation assessed seven types of models (analytical, empirical, small-scale experimental, full-scale experimental, multizone network, zonal, and CFD) for predicting ventilation performance in buildings, which can be different in details according to the model type. The analytical model can give an overall assessment of a ventilation system if the flow could be approximated to obtain an analytical solution. The empirical model is similar to the analytical model in terms of its capacities but is developed with a database. The small-scale model can be useful to examine complex ventilation problems if flow similarity can be maintained between the scaled model and reality. The full-scale model is the most reliable in predicting ventilation performance, but is expensive and time consuming. The multizone model is a useful tool for ventilation design in a whole building, but cannot provide detailed flow information in a room. The zonal model can be useful when a user has prior knowledge of the flow in a room. The CFD model provides the most detailed information about ventilation performance and is the most sophisticated. However, the model needs to be validated by corresponding experimental data and the user should have solid knowledge of fluid mechanics and numerical technique. Thus, the choice for an appropriate model depends on the problem.

11 ENGINES

Power generation and propulsion, electrical vehicles

11/01239 An experimental investigation on engine speed and cyclic dispersion in an HCCI engine
Ebrahimi, R. and Desmet, B. *Fuel*, 2010, 89, (8), 2149–2156.
This work presents the results of the experimental study on engine speed and cyclic dispersion in a homogeneous charge compression ignition (HCCI) engine. An engine TD43 is used to carry out the research. The combustion parameters are deduced from heat release rate which obtained from the first principle of thermodynamics during a cycle. The experimental results show that the duration of low temperature reaction plays an important role on HCCI combustion, particularly at higher engine speeds. Furthermore, cyclic dispersion in an HCCI engine presents, under certain operates conditions, a periodic behaviour corresponding to two or three cycles of the engine. It is concluded that the residual gas of a cycle modifies the three properties (temperature, dilution and composition) of gas in-cylinder at the following cycle. Therefore, gas residual directly affects the course of combustion in an HCCI engine. The knowledge of the duration of the different phases of combustion, as well as conditions in which the periodical appearance of misfire cycles occurs, is useful for the definition of regulation strategies.

11/01240 Dual-catalyst aftertreatment of lean-burn engine exhaust
Mirkelamoglu, B. *et al. Catalysis Today*, 2010, 151, (3–4), 386–394.
Pd/SZ catalysts prepared by a sol–gel technique were investigated with regards to their NO_2 selective catalytic reduction activity for application in a novel integrated NO–CO-hydrocarbon oxidation and NO_x-selective catalytic reduction system for the after-treatment of a lean-burn natural gas reciprocating engine exhaust. The dual-catalyst system consists of a mechanical mixture of a non-noble-metal-based oxidation catalyst component (Co/ZrO_2) for elimination of carbon monoxide and unburned hydrocarbons and oxidation of NO to NO_2 and a reduction catalyst component (Pd/SZ) for selective catalytic reduction (SCR) of NO_2 with CH_4. The effect of sol–gel preparation parameters on the activity of Pd/SZ was investigated. The zirconium alkoxide concentration was varied between 0.3 and 1.3 M during preparation of the Pd/SZ series of catalysts while other sol–gel parameters, such as hydrolysis and zirconium-to-sulfur precursor ratios and palladium loadings were kept constant. Pd/SZ prepared with the lowest concentration of alkoxide was mainly composed of metastable tetragonal zirconia while increasing alkoxide concentration resulted in decreased stability of t-ZrO_2 as evidenced by formation of m-ZrO_2 domains. Crystal phase of ZrO_2 was observed to have a significant effect on Pd dispersion. Palladium dispersion increased with increasing concentration of the monoclinic phase. The best performing Pd/SZ catalyst was further tested as the NO_x reduction catalyst component for simulated lean exhaust treatment over the dual-catalyst scheme where, N_2 yields in excess of 90% along with significant conversions of CO, CH_4, C_2H_6 and C_3H_8 were achieved at 450 °C. The NO_x reduction activity of Pd/SZ was significantly inhibited in the presence of water vapour. The presence of oxidation catalyst in close proximity to the reduction catalyst was shown to act to offset the effect of water vapour. Above 70% N_2 yield was achieved at 450 °C in the presence of 7% water vapour during simulated lean exhaust treatment over the dual-catalyst system.

11/01241 Effects of dimethyl-ether (DME) spray behavior in the cylinder on the combustion and exhaust emissions characteristics of a high speed diesel engine
Park, S. H. *et al. Fuel Processing Technology*, 2010, 91, (5), 504–513.
The purpose of this study was to analyse the exhaust emissions of DME fuel through experimental and numerical analyses of in-cylinder spray behaviour. To investigate this behaviour, spray characteristics such as the spray tip penetration, spray cone angle, and spray targeting point were studied in a re-entrant cylinder shape under real combustion chamber conditions. The combustion performance and exhaust emissions of the DME-fuelled diesel engine were calculated using KIVA-3V. The numerical results were validated with experimental results from a DME direct injection compression ignition engine with a single cylinder. The combustion pressure and IMEP have their peak values at an injection timing of around BTDC 30°, and the peak combustion temperature, exhaust emissions (soot, NO_x), and ISFC had a lower value. The HC and CO emissions from DME fuel showed lower values and distributions in the range from BTDC 25° to BTDC 10° at which a major part of the injected DME spray was distributed into the piston bowl area. When the injection timing advanced to before BTDC 30°, the HC and CO emissions showed a rapid increase. When the equivalence ratio increased, the combustion pressure and peak combustion temperature decreased, and the peak IMEP was retarded from BTDC 25° to BTDC 20°. In addition, NO_x emissions were largely decreased by the low combustion temperature, but the soot emissions increased slightly.

11/01242 Engine performance using emulsified diesel fuel
Alahmer, A. *et al. Energy Conversion and Management*, 2010, 51, (8), 1708–1713.
Emulsions of diesel and water are often promoted as being able to overcome the difficulty of simultaneously reducing emissions of both oxidizes of nitrogen (NO_x) and particulate matter from diesel engines. In this work, the performance of an engine together with its effect on environment were tested when engine was powered by both pure diesel and emulsified fuel with various quantities of water content in the diesel fuel. The amount of water quantities added ranged between 5% and 30% by volume. The engine speed during the experimental work was within the range from 1000 to 3000 rpm. While producing similar or greater thermal efficiency and improved NO_x emission outcomes use of the emulsion also results in an increase in brake specific fuel consumption. It was also found that, at high amount of water addition, the nitrogen oxide decreases. Also, in general, the diesel emulsion fuel emitted an amount of CO_2 higher than that of pure diesel.

11/01243 Equivalent turbocharger model of regulated two-stage turbocharging system
Liu, B. *et al. Journal of the Energy Institute*, 2010, 83, (4), 195–201.
A theoretical study on the regulated two-stage turbocharging (R2S) system is conducted based on the equivalent turbocharger concept. Expressions for the equivalent turbine flow area and the equivalent turbocharger efficiency of the R2S system were derived. The equivalent turbine flow area can be used in the analysis of the regulating capacity

of the R2S system, according to which the combination of the high- and low-pressure stage turbochargers is determined. The equivalent turbocharger efficiency gives the criteria for matching the R2S system with diesel engine, which is optimizing the exhaust energy distribution between the two-stage turbines to maintain high equivalent turbocharger efficiency. A computational analysis of the characteristic of the R2S system is included in this paper, and the application of the equivalent turbocharger model for matching and optimization of the R2S system is studied.

11/01244 Experimental investigation of the effect of compression ratio and injection pressure in a direct injection diesel engine running on Jatropha methyl ester

Jindal, S. *et al. Applied Thermal Engineering*, 2010, 30, (5), 442–448.

Being a fuel of different origin, the standard design parameters of a diesel engine may not be suitable for Jatropha methyl ester (JME). This study targets at finding the effects of the engine design parameters, namely compression ratio (CR) and fuel injection pressure (IP) jointly on the performance with regard to fuel consumption (BSFC), brake thermal efficiency (BTHE) and emissions of CO, CO_2, HC, NO_x and smoke opacity with JME as fuel. Comparison of performance and emission was done for different values of compression ratio along with injection pressure to find best possible combination for operating engine with JME. It is found that the combined increase of compression ratio and injection pressure increases the BTHE and reduces BSFC while having lower emissions. For small-sized direct injection constant speed engines used for agricultural applications (3.5 kW), the optimum combination was found as CR of 18 with IP of 250 bar.

11/01245 Experimental study of the autoignition of $C_8H_{16}O_2$ ethyl and methyl esters in a motored engine

Zhang, Y. and Boehman, A. L. *Combustion and Flame*, 2010, 157, (3), 546–555.

Autoignition of two biodiesel surrogates, methyl heptanoate and ethyl hexanoate, was studied in a motored CFR engine at an equivalence ratio of 0.25 and an intake temperature of 155 °C. The engine compression ratio was gradually increased from the lowest point (4.43) to the point where significant high temperature heat release (HTHR) occurred. Within the test range of this work, both of the two esters exhibited evident cool flame behaviour. At the same compression ratio, methyl heptanoate was observed to have both an earlier onset and a higher magnitude of low temperature heat release (LTHR) than ethyl hexanoate, indicating that methyl heptanoate is more reactive in the low temperature region than ethyl hexanoate. GC–MS analyses of the reaction intermediates from the oxidation of the two esters showed that the alkyl chain of fatty acid esters experiences the typical paraffin-like low temperature oxidation sequence. Based on the observations from GC–MS analyses, major low temperature oxidation pathways of ethyl hexanoate are proposed in this work. Also, it is observed that the abstraction of H-atoms on the α-carbon of the ester carbonyl group plays an important role in the oxidation of fatty acid esters. In addition, the identification of hexanoic acid among the reaction intermediates from low temperature oxidation of ethyl hexanaoate together with the observation of more fuel carbon being converted to C_2H_4 during ethyl hexanoate oxidation than during methyl heptanoate oxidation provide evidence for the existence of the six-centred unimolecular elimination reaction during low temperature oxidation of ethyl esters.

11/01246 Methodology to estimate the threshold in-cylinder temperature for self-ignition of fuel during cold start of Diesel engines

Broatch, A. *et al. Energy*, 2010, 35, (5), 2251–2260.

Cold startability of automotive direct injection (DI) diesel engines is frequently one of the negative features when these are compared to their closest competitor, the gasoline engine. This situation worsens with the current design trends (engine downsizing) and the emerging new Diesel combustion concepts, such as HCCI, PCCI, etc., which require low compression ratio engines. To mitigate this difficulty, pre-heating systems (glow plugs, air heating, etc.) are frequently used and their technologies have been continuously developed. For the optimum design of these systems, the determination of the threshold temperature that the gas should have in the cylinder in order to provoke the self-ignition of the fuel injected during cold starting is crucial. In this paper, a novel methodology for estimating the threshold temperature is presented. In this methodology, experimental and computational procedures are adequately combined to get a good compromise between accuracy and effort. The measurements have been used as input data and boundary conditions in 3D and 0D calculations in order to obtain the thermodynamic conditions of the gas in the cylinder during cold starting. The results obtained from the study of two engine configurations -low and high compression ratio- indicate that the threshold in-cylinder temperature is a single temperature of about 415 °C.

11/01247 Modeling of transport and chemistry in channel flows of automotive catalytic converters

Mladenov, N. *et al. Chemical Engineering Science*, 2010, 65, (2), 812–826.

A novel comprehensive numerical study is presented for a better understanding of mass transfer in channel flows with catalytically active walls at moderate temperatures and surface reaction rates. Altogether, 18 different numerical models are compared, which represent mass transfer in single channels of a honeycomb-type automotive catalytic converter operated under direct oxidation conditions. Three different channel geometries have been investigated: circular cross-section, square cross-section and square cross-section with rounded corners (fillets). One-dimensional plug-flow, two-dimensional boundary-layer and Navier–Stokes and three-dimensional Navier–Stokes equations are applied to model the reactor geometry. The diffusion limitation within the porous washcoat has been modelled by a simplified zero-dimensional effectiveness factor model as well as multidimensional reaction–diffusion models. Furthermore, simulations are also carried out for cases with instantaneous diffusion within the washcoat. All numerical models account for the coupled interactions of mass-transfer and heterogeneous chemistry within the channels. The chemical conversion of the pollutants on the platinum catalyst is described by an elementary-step-like heterogeneous reaction mechanism consisting of 74 reactions among 11 gas-phase species and 22 adsorbed surface species. The results of numerical simulations are compared with experimental data.

11/01248 Pd-promoted catalysts for low temperature diesel engine $DeNO_x$

Greenhalgh, B. *et al. Catalysis Today*, 2010, 151, (3–4), 285–290.

A series of promoted Pd catalysts supported on a mixed γ-Al_2O_3–TiO_2 support was prepared for use in selective catalytic reduction (SCR) of nitrogen oxides (NO_x) using hydrogen rich syngas as a reductant. The catalysts, containing Pd, Fe, Co and K incorporated through incipient wetness, were characterized in terms of surface area, elemental composition and crystalline chemical phase. The NO_x reduction ($DeNO_x$) activity of the catalyst series was measured as a function of temperature in a flow reactor system fed with a simulated diesel engine exhaust. The catalyst series shows high NO_x conversion and favourable selectivity to N_2 over a wide range of temperature compared to results on similar catalyst systems reported to date.

11/01249 Performance of diesel engine using gas mixture with variable specific heats model

Sakhrieh, A. *et al. Journal of the Energy Institute*, 2010, 83, (4), 217–224.

A thermodynamic, one-zone, zero-dimensional computational model for a diesel engine is established in which a working fluid consisting of various gas mixtures has been implemented. The results were compared to those that use air as the working fluid with variable specific heats. Most of the parameters that are important for compression ignition engines, such as equivalence ratio, engine speed, maximum temperature, gas pressure, brake mean effective pressure and cycle thermal efficiency, have been studied. Furthermore, the effect of boost pressure was studied using both the gas mixture and dependent temperature air models. It was found that the temperature-dependent air model overestimates the maximum temperature and cylinder pressure. For example, for the air model, the maximum temperature and cylinder pressure were about 1775 K and 93.5 bar, respectively, at 2500 rev min^{-1}, and the fuel/air equivalence ratio $\Omega = 0.6$. On the other hand, when the gas mixture model is used under the same conditions, the maximum temperature and cylinder pressure were 1685 K and 87.5 bar, respectively. This is reflected on the brake mean effective pressure and cycle thermal efficiency, both of which were overestimated in when using the temperature-dependent air model. The conclusions obtained in this study are useful when considering the design of diesel engines.

11/01250 Research on fault detection and identification of gas turbines sensors based on wavelet entropy

Chen, J. *et al. Journal of the Energy Institute*, 2010, 83, (4), 202–209.

Thermal parameters are usually used in the computation and assessment of gas turbine power plant performance. It is very important to obtain accurate and real values of thermal parameters. Since the measured values of parameters are directly affected by sensor state, it is necessary to detect and identify sensor fault promptly. Wavelet entropy was used to extract wavelet coefficients, since it is a good measure of signal distribution. A definition of the wavelet entropy and the calculation methods is introduced, and then its advantage over other wavelet methods on fault detection are given. Furthermore, it is shown that wavelet entropy is independent of fault amplitude. Through simulation, features of different faults were extracted and analysed. Based on the above analysis and calculation, a method for sensor fault

detection and identification was advanced and shown by experimental data. The prospects of engineering application in sensor fault detection and identification are discussed.

11/01251 The characteristics of performance and exhaust emissions of a diesel engine using a biodiesel with antioxidants

Ryu, K. *Bioresource Technology*, 2010, 101, (S1), S78–S82.

The aim of this study is to investigate the effects of antioxidants on the oxidation stability of biodiesel fuel, the engine performance and the exhaust emissions of a diesel engine. Biodiesel fuel used in the study was derived from soybean oil. The results show that the efficiency of antioxidants is in the order TBHQ > PrG > BHA > BHT > α-tocopherol. The oxidative stability of biodiesel fuel attained the 6-h quality standard with 100 ppm butylhydroquinone (TBHQ) and with 300 ppm PrG in biodiesel fuel. Combustion characteristics and exhaust emissions in diesel engine were not influenced by the addition of antioxidants in biodiesel fuel. The break specific fuel consumption (BSFC) of biodiesel fuel with antioxidants decreased more than that of biodiesel fuel without antioxidants, but no trends were observed according to the type or amount of antioxidant. Antioxidants had few effects on the exhaust emissions of a diesel engine running on biodiesel.

11/01252 Total OH reactivity and VOC analyses for gasoline vehicular exhaust with a chassis dynamometer

Nakashima, Y. *et al. Atmospheric Environment*, 2010, 44, (4), 468–475.

Total OH reactivity for the exhaust gas of gasoline vehicles was measured for the first time under nine different driving conditions with a chassis dynamometer at the National Institute for Environmental Studies (NIES). Along with the total OH reactivity measurements, analysis of trace species such as CH_4, CO, NO, NO_2, and 56 kinds of volatile organic compounds (VOCs), including two aldehydes, was carried out. The ratio of alkanes to alkenes in the exhaust gas turned out to depend on the condition of the driving cycles. There were a considerable number of unidentified peaks obtained during GC analysis. About 15–30% of the total carbon was unidentified species. The chemical compositions of vehicular exhaust were found to depend on the temperature of the engine or catalysts. The contribution of OH reactivity to the species obtained depended on the temperature condition for the engine. The calculated total OH reactivity for VOCs was compared with ozone formation potential (OFP) and it turned out that there are in good correlation, while the correlation for 'Cold' start deviates from that for 'Hot' start. The measured and calculated OH reactivities were compared with each other. For all driving cycles, the calculated OH reactivity was confirmed to be an underestimation, implying the existence of unknown species in the exhaust gas. The percentage contribution of OH reactivity to the unknown species during 'Cold' start was about 17.5%, which was almost the same as that for 'Hot' start at 17.0%. However, the absolute value of OH reactivity for 'Cold' start was about ten times higher than that for 'Hot' start.

Hybrid engine systems

11/01253 An experimental investigation on engine performance and emissions of a supercharged H_2-diesel dual-fuel engine

Roy, M. M. *et al. International Journal of Hydrogen Energy*, 2010, 35, (2), 844–853.

This study investigated the engine performance and emissions of a supercharged engine fuelled by hydrogen and ignited by a pilot amount of diesel fuel in dual-fuel mode. The engine was tested for use as a cogeneration engine, so power output while maintaining a reasonable thermal efficiency was important. Experiments were carried out at a constant pilot injection pressure and pilot quantity for different fuel-air equivalence ratios and at various injection timings without and with charge dilution. The experimental strategy was to optimize the injection timing to maximize engine power at different fuel-air equivalence ratios without knocking and within the limit of the maximum cylinder pressure. The engine was tested first with hydrogen-operation condition up to the maximum possible fuel-air equivalence ratio of 0.3. A maximum IMEP of 908 kPa and a thermal efficiency of about 42% were obtained. Equivalence ratio could not be further increased due to knocking of the engine. The emission of CO was only about 5 ppm, and that of HC was about 15 ppm. However, the NO_x emissions were high, 100–200 ppm or more. The charge dilution by N_2 was then performed to obtain lower NO_x emissions. The 100% reduction of NO_x was achieved. Due to the dilution by N_2 gas, higher amount of energy could be supplied from hydrogen without knocking, and about 13% higher IMEP was produced than without charge dilution.

11/01254 An experimental study of the biogas–diesel HCCI mode of engine operation

Nathan, S. S. *et al. Energy Conversion and Management*, 2010, 51, (7), 1347–1353.

In this work biogas was used in a HCCI engine with charge temperature and amount of diesel injected into the intake manifold being used to control combustion. The presence of CO_2 in biogas suppresses the high heat release rates encountered with neat diesel fuelling in HCCI engines. Normally biogas use leads to a drop in thermal efficiency in both SI and CI engines. However, present results indicate that thermal efficiencies close to diesel engine values can be obtained in the HCCI mode. The NO level was less than 20 ppm and the smoke level was less than 0.1 BSU at all conditions. The best energy ratio was 50%. HC levels were very high and were lowered when the charge temperature was raised. A charge temperature of about 80–135 °C was needed, which can be attained though heating by exhaust gases. On the whole the HCCI mode can be a viable option to utilize biogas in a diesel engine.

11/01255 Effect of biodiesel unsaturated fatty acid on combustion characteristics of a DI compression ignition engine

Puhan, S. *et al. Biomass and Bioenergy*, 2010, 34, (8), 1079–1088.

This study focuses on the effect of biodiesel molecular weight, structure (*cis* and *trans*), and the number of double bonds on the diesel engine operation characteristics. Three types of biodiesel with different molecular weight and number of double bond were selected for the experimental studies. The biodiesels were prepared and analysed for fuel properties according to the standards. A constant speed diesel engine, which develops 4.4 kW of power, was run with biodiesels and its performance was compared with diesel fuel. The results show that linseed oil methyl ester with high linolenic (unsaturated fatty acid ester) does not suit best for diesel engine due to high oxides of nitrogen emission and low thermal efficiency.

11/01256 Experimental investigation on a DI diesel engine fuelled with Madhuca Indica ester and diesel blend

Saravanan, N. *et al. Biomass and Bioenergy*, 2010, 34, (6), 838–843.

Biodiesel is a fatty acid alkyl ester, which is renewable, biodegradable and non-toxic fuel which can be derived from any vegetable oil by transesterification. One of the popularly used biodiesel in India is Mahua oil (*Madhuca indica*). In the present investigation Mahua oil was transesterified using methanol in the presence of alkali catalyst and was used to study the performance and emission characteristics. The biodiesel was tested on a single cylinder, four stroke compression ignition engine. Engine performance tests showed that power loss was around 13% combined with 20% increase in fuel consumption with Mahua oil methyl ester at full load. Emissions such as carbon monoxide, hydrocarbon were lesser for Mahua ester compared to diesel by 26% and 20% respectively. Oxides of nitrogen were lesser by 4% for the ester compared to diesel.

11/01257 Experimental investigation on dual fuel operation of acetylene in a DI diesel engine

Lakshmanan, T. and Nagarajan, G. *Fuel Processing Technology*, 2010, 91, (5), 496–503.

Depletion of fossils fuels and environmental degradation have prompted researchers throughout the world to search for a suitable alternative fuel for diesel engine. One such step is to utilize renewable fuels in diesel engines by partial or total replacement of diesel in dual fuel mode. In this study, acetylene gas has been considered as an alternative fuel for compression ignition engine, which has excellent combustion properties. Investigation has been carried out on a single cylinder, air cooled, direct injection (DI), compression ignition engine designed to develop the rated power output of 4.4 kW at 1500 rpm under variable load conditions, run on dual fuel mode with diesel as injected primary fuel and acetylene inducted as secondary gaseous fuel at various flow rates. Acetylene aspiration resulted in lower thermal efficiency. Smoke, HC and CO emissions reduced, when compared with baseline diesel operation. With acetylene induction, due to high combustion rates, NO_x emission significantly increased. Peak pressure and maximum rate of pressure rise also increased in the dual fuel mode of operation due to higher flame speed. It is concluded that induction of acetylene can significantly reduce smoke, CO and HC emissions with a small penalty on efficiency.

11/01258 Oxidation chemistry of cyclic hydrocarbons in a motored engine: methylcyclopentane, tetralin, and decalin

Yang, Y. and Boehman, A. L. *Combustion and Flame*, 2010, 157, (3), 495–505.

This work is concerned with the oxidation chemistry of methylcyclopentane (MCP), 1,2,3,4-tetrahydronaphthalene (tetralin) and decahydronaphthalene (decalin) in a motored engine at low to intermediate temperatures. The experiment is conducted with variable compression ratio from 4 to 15 at equivalence ratio of 0.25 and fixed intake

temperature. Results show different reactivity in low temperature oxidation for the three compounds. MCP and tetralin show little low temperature reaction prior to autoignition, while decalin shows significant low temperature reactivity. Detailed product analysis showed that conjugate olefins, the olefin having the identical structure with the reactant except the only C=C bond, account for over 70% of the products from MCP and an even higher percentage of the products from tetralin. Tetralin oxidation under the present conditions is essentially oxidative dehydrogenation with little oxygenated cyclic compound being formed. Hydronaphthalenes with various degrees of unsaturation are detected in the products from decalin, but are not as prevalent as in the case of MCP and tetralin, because of the high selectivity toward low temperature chain branching. The ring-opening paths in decalin oxidation are discussed, suggesting that breaking the common C–C bond of the two rings is more likely than opening the two rings one after the other. Methyl substitution on the ring was found to significantly promote the formation of propene relative to ethene. Reaction mechanisms are proposed to explain the major products formed from each compound.

11/01259 Performance and exhaust emission characteristics of a spark ignition engine using ethanol and ethanol-reformed gas

Park, C. *et al. Fuel*, 2010, 89, (8), 2118–2125.

Since ethanol is a renewable source of energy and has lower CO_2 emissions than gasoline, ethanol produced from biomass is expected to be used more frequently as an alternative fuel. It is recognized that for spark ignition (SI) engines, ethanol has the advantages of high octane and high combustion speed and the disadvantage of ignition difficulties at low temperatures. An additional disadvantage is that ethanol may cause extra wear and corrosion of electric fuel pumps. On-board hydrogen production out of ethanol is an alternative plan. Ethanol has been used in Brazil as a passenger vehicle fuel since 1979, and more than six million vehicles on US highways are flexible fuel vehicles (FFVs). These vehicles can operate on E85 – a blend of 85% ethanol and 15% gasoline. This paper investigates the influence of ethanol fuel on SI engine performance, thermal efficiency and emissions. The combustion characteristics of hydrogen enriched gaseous fuel made from ethanol are also examined. Ethanol has excellent anti-knock qualities due to its high octane number and a high latent heat of evaporation, which makes the temperature of the intake manifold lower. In addition to the effect of latent heat of evaporation, the difference in combustion products compared with gasoline further decreases combustion temperature, thereby reducing cooling heat loss. Reductions in CO_2, nitrogen oxide and total hydrocarbons combustion products for ethanol vs gasoline are described.

11/01260 Preventive knock protection technique for stationary SI engines fuelled by natural gas

Saikaly, K. *et al. Fuel Processing Technology*, 2010, 91, (6), 641–652.

In a combined heat and power (CHP) plant, spark ignition engines must operate at their maximum power to reduce the pay back time. Because of environmental and economic concerns, engines are set with high compression ratios. Consequently, optimal operating conditions are generally very close to those of knock occurrence and heavy knock can severely damage the engine piston. There are two main protection techniques: the curative one commonly used by engine manufacturers and well documented in the literature and the preventive one based on a knock prediction according to the quality of the supplied gas. The indicator used to describe gas quality is the methane number (MN). The methane number requirement (MNR) of the engine is defined, for an engine set (spark advance, air–fuel ratio, and load), as the minimum value of MN above which knock free operation is ensured. To prevent knock occurrence, it is necessary to adapt the engine tuning according to variable gas composition. The objective of the present work is to validate the concept of knock preventive protection. First, a prediction of MNR according to engine settings is computed through a combustion simulator composed of a thermodynamic two-zone model. Predicted MNR are compared to experimental results performed on a single-cylinder SI gas engine and show good agreement with numerical results (uncertainty below 1 point). Then, the combustion simulator is used to generate a protection mapping. At last, the knock preventive protection was successfully tested.

11/01261 Simulation of compression engine powered by biofuels

Hamdan, M. A. and Khalil, R. H. *Energy Conversion and Management*, 2010, 51, (8), 1714–1718.

The present work describes a theoretical investigation concerning the performance of a four strokes compression engine, which is powered by alternative fuels in the form of diesel–ethanol and diesel–ether mixtures, the properties of which were sited from literature. The amount of each alcohol added was 5%, 10% and 15% by volume. The engine speed during the experimental work was within the range from 1000 to 4000 rpm, with engine was set at full throttle opening and hence the engine was operating under full load conditions. Several parameters were calculated namely: engine torque, brake mean effective pressure, brake power, specific fuel consumption and the thermal efficiency, this was carried out using DIESEL-RK software. It was found that the engine is of highest thermal efficiency when it is powered by a 15% ethanol–diesel blend, wile it is of minimum thermal efficiency when it is powered by pure diesel fuel. Further, it was found that both the thermal efficiency of the engine and the specific fuel consumption increases with the percentage of either ethanol or ether in the fuel blend. However, the power was found to decrease with the amount of either ethanol or ether in the fuel blends.

11/01262 Thermodynamic characteristics of a low concentration methane catalytic combustion gas turbine

Yin, J. *et al. Applied Energy*, 2010, 87, (6), 2102–2108.

Low concentration methane, emitted from coal mines, landfill, animal waste, etc. into the atmosphere, is not only a greenhouse gas, but also a waste energy source if not utilized. Methane is 23 times more potent than CO_2 in terms of trapping heat in the atmosphere over a timeframe of 100 years. This paper studies a novel lean burn catalytic combustion gas turbine, which can be powered with about 1% methane (volume) in air. When this technology is successfully developed, it can be used not only to mitigate the methane for greenhouse gas reduction, but also to utilize such methane as a clean energy source. This paper presents study results on the thermodynamic characteristics of this new lean burn catalytic combustion gas turbine system by conducting thermal performance analysis of the turbine cycle. The thermodynamic data including thermal efficiencies and exergy loss of main components of the turbine system are presented under different pressure ratios, turbine inlet temperatures and methane concentrations.

Transport battery development

11/01263 Energy management of an FC/UC hybrid vehicular power system using a combined neural network-wavelet transform based strategy

Ates, Y. *et al. International Journal of Hydrogen Energy*, 2010, 35, (2), 774–783.

An energy management strategy (EMS) is one of the most important issues for the efficiency and performance of a hybrid vehicular system. This paper deals with a neural network and wavelet transform based EMS proposed for a fuel cell/ultra-capacitor hybrid vehicular system. The proposed method combines the capability of wavelet transform to treat transient signals with the ability of auto-associative neural network supervisory mode control. The main originality of the paper is related with the application of neural network instead of another intelligent control method, fuzzy logic, which is presented in the recent publication of the authors, and the combination of neural network-wavelet transform approaches. Then, the effectiveness comparison of both methods considering one of the most important points in a vehicular system, fuel consumption (or hydrogen consumption), is realized. The mathematical and electrical models of the hybrid vehicular system are developed in detail and simulated using MATLAB®, Simulink® and SimPowerSystems® environments.

11/01264 Method to release hydrogen from ammonia borane for portable fuel cell applications

Diwan, M. *et al. International Journal of Hydrogen Energy*, 2010, 35, (2), 577–584.

Ammonia borane (AB, NH_3BH_3) is considered to be a promising hydrogen storage material as it contains 19.6 wt% hydrogen. It is difficult, however, to release hydrogen from AB. Thermolysis, catalytic hydrolysis and heat generated by additional reactive mixtures are usually employed, but these methods have disadvantages that limit their use for portable applications. This paper demonstrates a new approach to release hydrogen, which does not require any catalyst and produces relatively high hydrogen yield and environmentally benign byproducts. It involves nano-aluminium (nAl)/water combustion reaction, which provides heat for AB dehydrogenation and releases additional hydrogen from water. To facilitate higher H_2 yield from thermolysis, as compared to hydrolysis, AB is spatially separated from the nAl/water mixture using a concentric cylindrical container. The effect of the container design on hydrogen generation is studied and optimized. This study also includes transient temperature and pressure measurements, and product characterization using mass spectrometer and ^{11}B NMR. This approach provides H_2 yield up to 9.5 wt% on material basis. The experimental results and analysis show that a proposed power source based on this method is promising for portable electronic devices.

11/01265 Sustainable transportation based on electric vehicle concepts: a brief overview
Eberle, U. and von Helmolt, R. *Energy & Environmental Science*, 2010, 3, (6), 689–699.
The energy storage system is of decisive importance for all types of electric vehicles, in contrast to vehicles powered by a conventional fossil fuel or biofuel-based internal combustion engine. Two major alternatives exist: (1) electrical energy storage using batteries and (2) chemical energy storage as hydrogen and the application of a fuel cell as energy converter. Pure battery electrical vehicles are limited to ranges within 100 miles, however extended-range electric vehicles (E-REV) and hydrogen fuel cell vehicles (fuel cell electric vehicles, FCEV) can achieve longer distances and are being investigated further by General Motors and Opel. The purchase cost for these vehicles is likely to be high when they first come to market and there are likely to be initial technological limitations compared to conventional vehicles, therefore the support and cooperation of car manufacturers, energy companies and governments will be needed, as well as the end consumer.

12 REFRACTORIES/ CERAMICS

Properties, production, applications

11/01266 Active thermal insulators: finite elements modeling and parametric study of thermoelectric modules integrated into a double pane glazing system
Van Dessel, S. *et al. Energy and Buildings*, 2010, 42, (7), 1156–1164.
Active thermal insulators (ATI) represent a new thermal control technology that uses solar energy to compensate for the passive heat losses or gains in building envelopes. This effect is accomplished by integrating photovoltaic (PV) and thermoelectric (TE) systems into a wall assembly. A parametric study is presented considering the implementation of TE-modules into the air cavity of a double pane glazing system. The main objectives of this study are to explore design configurations that maximize the coefficient of performance of the TE-heat pump units, and maximize the ability of the system to perform as a heating and cooling system for use in buildings. A finite elements model was developed and experimentally validated to calculate the steady-state heat transfer for the ATI-system. A parametric study was undertaken to determine: (i) suitable TE-modules for this application, (ii) the optimal spreading of the TE-heat pumps, and (iii) the composition of the double glazing unit. The study's results indicate that the system can be properly designed for heating purposes, however, a more optimal design will need to be realized in order to make the approach effective for cooling applications.

11/01267 Code compliance of fully glazed tall office buildings in hot climate
Assem, E. O. and Al-Mumin, A. A. *Energy and Buildings*, 2010, 42, (7), 1100–1105.
In this research, the effect of glazing type and other energy conservation measures on the peak power demand of air-conditioning (AC) systems is investigated for tall and fully glazed government and private office buildings. The EnergyPlus building simulation program is used in the analysis assuming climate conditions similar to that experienced in hot countries of the Arabian Gulf, such as Kuwait. The main objective of the investigation is to meet the limits stipulated in the mandatory Kuwaiti code of practice for energy conservation, with respect to peak AC demand, for both air-cooled and water-cooled AC systems. It is found that for government office buildings with air-cooled AC system, the code limit of 70 W/m^2 for the AC peak power is met when tint low-e glazing is used with either heat recovery units or with AC systems with higher coefficient of performance (COP); whereas for private office buildings, the limit can be met when using a number of conservation measures. Overall, the water-cooled AC system showed better performance even though the code limit is 50 W/m^2 which is mainly due to the higher COP values achievable with such AC systems.

11/01268 Effects of iron content on the structural evolution, electrical properties and thermochemical stability of $BaCo_{0.9-x}Fe_xNb_{0.1}O_{3-\delta}$ ceramic membrane
Zhang, J. *et al. International Journal of Hydrogen Energy*, 2010, 35, (2), 814–820.
Cubic perovskite oxygen permeation materials $BaCo_{0.9-x}Fe_xNb_{0.1}O_{3-\delta}$ (BCFN, $x = 0.1$–0.7) are prepared by the conventional solid state reaction process. The crystal structure development, structural stability, electrical conductivity and oxygen permeation flux are investigated. The introduction of iron makes the formation of cubic perovskite structure for BCFN materials much easier. BCFN exhibits a p-type semiconductor and obeys the thermally activated small polarons hopping mechanism. The electrical conductivity of BCFN increases with increasing temperature and decreases with the Fe-doping concentration. The incorporation of Fe decreases slightly the oxygen permeability of BCFN membranes, but enhances significantly the structure stability of the oxygen permeation membrane in reducing atmosphere. A high oxygen permeation flux of 1.7 $ml\,cm^{-2}\,min^{-1}$ at 900 °C through 1 mm densified membrane under air/helium condition is obtained for the composition of $BaCo_{0.6}Fe_{0.3}Nb_{0.1}O_{3-\delta}$.

11/01269 Experimental study of cooling effects of a passive evaporative cooling wall constructed of porous ceramics with high water soaking-up ability
He, J. and Hoyano, A. *Building and Environment*, 2010, 45, (2), 461–472.
As a passive cooling strategy aimed at controlling increased surface temperatures and creating cooler urban environments in summer, the authors developed a passive evaporative cooling wall (PECW) constructed of porous ceramics. These ceramics possess a capillary force to soak up water, which means that their vertical surface is wet up to a level higher than 100 cm when their lower end is placed in water. The present paper describes an experiment that clarifies the cooling effects of a prototype PECW constructed of pipe-shaped ceramics. The PECW is capable of absorbing water and allows wind penetration, thus reducing its surface temperature by means of water evaporation. Passive cooling effects such as solar shading, radiation cooling, and ventilation cooling can be enhanced by incorporating PECWs into the design of outdoor or semi-outdoor spaces in parks, pedestrian areas and residential courtyards. The following findings were understood from an experimental data collected over a summer period. Wet vertical surfaces of the ceramic pipe reached a height of over 1 m at an outdoor location exposed to solar radiation. Wet surface conditions can be maintained throughout successive sunny days during summer. A slight difference in the vertical surface temperatures of the ceramic pipe was found. The air passing through the PECW was cooled, and its temperature can be reduced to a minimum value by several degrees during summer daytime. It was also found that the surface temperature of the shaded ceramic pipe can be maintained at a temperature nearly equal to the wet-bulb temperature of outdoor air.

11/01270 Influence of windows on the energy balance of apartment buildings in Amman
Hassouneh, K. *et al. Energy Conversion and Management*, 2010, 51, (8), 1583–1591.
The influence of windows on the energy balance of apartment buildings in Amman is investigated by using self developed simulation software (SDS) based on the ASHRAE tables for solar heat gain calculation and coaling load factor for latitude 32°, where Amman city is located. The calculations of energy saving are made to find out the influence of windows on the energy balance of apartment buildings in Amman. Also, the present investigation aimed to study the energy performance of windows of an apartment building in Amman in order to select the most energy efficient windows that can save more energy and reduce heating load in winter, the percentage of saving energy and saving fuel and money through time. Variations of type of glazing using eight types of glazing (clear glass, types A, B, C, D, E, F and G) are made to find out the most appropriate type of glazing in each direction. Also the orientation of window is changeable in the main four directions (north, south, east and west). The area of glazing varies also in different orientation to find the influence of window area on the thermal balance of the building. The results show that if energy efficient windows are used, the flexibility of choosing the glazed area and orientation increases. It has been found that choosing a larger area facing south, east and west can save more energy and decrease heating costs in winter using certain types of glazing such as glass type A and clear glass, while decreasing the glazing area facing north can save money and energy. However, it has been found that the energy can be saved in the north direction if glass type B has been used. In the apartment building, it is found that certain combination of glazing is energy efficient than others. This combination consists of using large area of glass type A in the east, west and south direction, and glass type B in the north direction or reducing glazing area as possible in the north direction.

11/01271 Processing and properties of aligned multi-walled carbon nanotube/aluminoborosilicate glass composites made by sol–gel processing
Otieno, G. *et al. Carbon*, 2010, 48, (8), 2212–2217.

This paper desribes a sol–gel-based approach for producing aluminoborosilicate glass composites containing continuous, aligned carbon nanotubes. The process involves the production of aligned carbon nanotubes (ACNT) via aerosol chemical vapour deposition (CVD), followed by infiltration of the ACNT with aluminoborosilicate sol. The advantages of this process are three-fold: (1) aerosol CVD is an efficient method of producing clean, aligned arrays of CNTs, (2) sol–gel chemistry provides a simple route to infiltration of the ACNTs, and (3) carbon nanotube (CNT) agglomeration problems associated with CNT composites are circumvented. ACNTs (carpets) with heights of up to 4.4 mm were grown with areas of $10\,mm \times 20\,mm$ for composite fabrication. The composite showed extensive pullout of the CNTs on a fracture surface and improved thermal and electrical conductivities of $16\,W\,m^{-1}\,K^{-1}$ and $5–8 \times 10^2\ S\,m^{-1}$ respectively compared with only $1.2\,W\,m^{-1}\,K^{-1}$ and $10^{-13}\,S\,m^{-1}$ for the monolithic glass.

13 ALTERNATIVE ENERGY SUPPLIES

Biofuels and bioconversion energy

11/01272 An environment-friendly thermal insulation material from cotton stalk fibers

Zhou, X. *et al. Energy and Buildings*, 2010, 42, (7), 1070–1074.

A new environment-friendly thermal insulation material – binderless cotton stalk fibreboard (BCSF) made from cotton stalk fibres with no chemical additives was developed using high frequency hot-pressing. The goal of this paper was to investigate the effect of board density, fibre moisture content (MC) and pressing time on thermal conductivity and mechanical properties of BCSF. The results showed that the board with a density of 150–450 kg/m^3 had the thermal conductivity values ranging from 0.0585 to 0.0815 W/m K, which was close to that of the expanded perlite and vermiculite within the same density range. The thermal conductivity values had a strong linear correlation with the board density. The internal bonding strength (IBS) of boards was good at the relatively low-density level, which can be significantly improved with increasing the fibre MC and prolonging pressing time. The same trend was observed for modulus of rapture (MOR) and modulus of elasticity (MOE) of the boards. As an environment-friendly and renewable material, the BCSF is particularly suitable for ceiling and wall applications to save energy.

11/01273 Assessing the sustainability of Brazilian oleaginous crops – possible raw material to produce biodiesel

Takahashi, F. and Ortega, E. *Energy Policy*, 2010, 38, (5), 2446–2454.

The aim of this paper is to make an emergy assessment of oleaginous crops cultivated in Brazil, available to produce biodiesel, in order to determine which crop is the most sustainable. This study evaluates conventional agro-chemical farms that produce rapeseed (canola), oil palm, soybean, sunflower and cotton. Rapeseed (canola) crop uses 40.41% of renewable energy and it is the most sustainable conventional oil crop; on the other hand, it is not widely produced in Brazil, probably due to climate restrictions or low market demand. The oil palm emergy indicators are contradictory: its emergy exchange ratio (EER) value is the lower, showing the possibility of fair exchange, and the low transformity value indicates high efficiency; however, it also has low renewability (28.31%), indicating a high dependency on agro-chemicals (basically fertilizers). Oil palm is a potential energy source due to its high agricultural productivity, but appropriate management is necessary to increase its sustainability and reduce the use of non-renewable resources.

11/01274 Briquetting soda weed (*Salsola tragus*) to be used as a rural fuel source

Yumak, H. *et al. Biomass and Bioenergy*, 2010, 34, (5), 630–636.

Amount of traditional fuel sources in the world has been decreasing and there is a definite need to produce and utilize alternative fuels such as biomass materials. In this study, briquetting conditions of Russian tumbleweed, *Salsola tragus* (commonly named soda weed in Turkey), which grows in salty soils were investigated. Soda weeds were first chopped coarsely in a local thresher, then chopped finely in a hammer mill. Weed materials at three moisture levels (7%, 10% and 13%) were prepared in the lab. Chopped weed materials were filled in cylindrical and square dies and compressed using a hydraulic press at three pressure levels of 15.7, 19.6 and 31.4 MPa. Optimum temperature, moisture rate, and pressure values were determined to produce stable briquettes. Further experiments were conducted to produce briquettes using sawdust and walnut shells as additives in conical dies of two different sizes. Results of a statistical analysis of parameters to produce briquettes in different dies indicated that moisture rates of 7–10%, pressure of 31.4 MPa, and temperatures of 85–105 °C were suitable for briquetting soda weed. Furthermore, sawdust and walnut shells additives increased briquette density without any negative effects on production process and product stability.

11/01275 Clean bio-oil production from fast pyrolysis of sewage sludge: effects of reaction conditions and metal oxide catalysts

Park, H. J. *et al. Bioresource Technology*, 2010, 101, (S1), S83–S85.

Fast pyrolysis of sewage sludge was carried out under different reaction conditions, and its effects on bio-oil characteristics were studied. The effect of metal oxide catalysts on the removal of chlorine in the bio-oil was also investigated for four types of catalysts. The optimal pyrolysis temperature for bio-oil production was found to be 450 °C, while much smaller and larger feed sizes adversely influenced production. Higher flow and feeding rates were more effective but did not greatly affect bio-oil yields. The use of the product gas as the fluidizing medium gave an increased bio-oil yield. Metal oxide catalysts (CaO and La_2O_3) contributed to a slight decrease in bio-oil yield and an increase in water content but were significantly effective in removal of chlorine from the bio-oil. The fixed catalyst bed system exhibited a higher removal rate than when metal oxide-supported alumina was used as the fluidized bed material.

11/01276 Cleaner gasoline production by using glycerol as fuel extender

Kiatkittipong, W. *et al. Fuel Processing Technology*, 2010, 91, (5), 456–460.

Glycerol, a major by-product of biodiesel production, was employed as a fuel extender in this study. The process was originally investigated by etherifying the entire fluidized catalytic cracking (FCC) gasoline with glycerol. The reactions were carried out in a pressurized liquid phase reactor in the presence of three different catalysts (i.e. Amberlyst 16, Amberlyst 15, and β-zeolite) at 70 °C and 2.6 MPa with a volume ratio of FCC gasoline to glycerol ratio of 84:16 for 10 h. The catalytic activity could be ordered as Amberlyst 16 > Amberlyst 15 $\gg$ β-zeolite. The properties of FCC and etherified FCC products were determined by the standard analysis of Research Octane Number (RON), blending Reid vapour pressure (bRvp), distillation temperature following the standard methods of ASTM D-2699, ASTM D-5191 and ASTM D-86, respectively. It was found that the olefin content decreased opposing with increasing of octane number due to ethers of glycerol formation and the etherified gasoline product has lower bRvp than that of original FCC gasoline. The process of FCC gasoline etherification with glycerol showed great environmental benefits; in addition, ethers produced renewably from glycerol could extend the gasoline volume.

11/01277 Comparison of the thermal reactivities of isolated lignin and holocellulose during pyrolysis

Haykiri-Acma, H. *et al. Fuel Processing Technology*, 2010, 91, (7), 759–764.

Woody shells of Turkish hazelnuts which are rich in lignin content offer an important potential as a renewable energy source. Hence, this study focuses on the investigation of the thermal reactivities of the real macromolecular ingredients of this biomass species. Hazelnut shells were treated with chemicals to isolate its holocellulose (hemicelluloses + cellulose) and lignin. Scanning electron microscopy images revealed the significant differences between the physical features of the untreated biomass and its isolated ingredients. Thermal properties of the biomass and these ingredients were examined by thermogravimetric analysis and differential scanning calorimetry techniques under non-isothermal pyrolysis conditions from ambient to 900 °C. It was found that unlike holocellulose, lignin slowly decomposes in a wider temperature range, and its decomposition is associated with exothermic heat flow. It was also concluded that the hemicellulosics in holocellulose have very important effects with respect to the char yield and the exothermicity of the process. Besides, inorganics in biomass play a catalytic role during pyrolysis. The activation energies calculated according to Borchardt–Daniels' kinetic model were 64.8 and 51.8 kJ/mol for the pyrolysis of holocellulose and lignin, respectively, and each of them is higher than that for the untreated biomass.

11/01278 Continuous production of biodiesel in a packed-bed reactor using shell–core structural $Ca(C_3H_7O_3)_2/CaCO_3$ catalyst

Hsieh, L.-S. *et al. Chemical Engineering Journal*, 2010, 158, (2), 250–256.

The continuous production of biodiesel was studied by using a steady-state packed-bed reactor. The shell–core $Ca(C_3H_7O_3)_2/CaCO_3$ solid-base catalyst was prepared with a mechanical strong core of $CaCO_3$ for

continuous transesterification of soybean oil in a packed-bed reactor. Alcohol–oil ratio, retention time and reaction temperature were evaluated to obtain optimum reaction conditions. The yield of fatty acid methyl esters (FAME, i.e. biodiesel) achieved 95% at the reaction temperature 60 °C, alcohol–oil molar ratio of 30:1 and retention time of 168 min. The reusability of catalyst was checked up to five cycles and found negligible decrease in the catalyst activity. Water in the oil can significantly decrease the yield due to the deactivation of $Ca(C_3H_7O_3)_2$ and hydrolysis of FAME. The transesterification of soybean oil, canola oil and sunflower oil also was compared with model compound, triolein, using powder $Ca(C_3H_7O_3)_2$ in the batch reactor. Although these oils contained different triglyceride mixtures, their FAME yields were comparable. A Langmuir–Hinshelwood rate equation was established for the transesterification of soybean oil with methanol. Regression of experimental data indicated that the transesterification was an endothermic reaction with the enthalpy change of 23,504 J/mol and the activation energy was 42,096 J/mol.

11/01279 Effective control of membrane fouling by filamentous bacteria in a submerged membrane bioreactor

Wang, Z. *et al. Chemical Engineering Journal*, 2010, 158, (3), 608–615.

Two identical submerged membrane bioreactors (MBRs) for synthetic wastewater treatment were operated in parallel under different dissolved oxygen (DO) levels for over 3 months in this study. The digital biological microscopy, particle size distribution (PSD) analysis, gel filtration chromatography, three-dimensional excitation-emission matrix fluorescence spectroscopy, and column chromatographic method, etc. were used to identify the difference between bulking sludge (BS) caused by filamentous bacteria (low DO operation, about 0.4 mg/L) and normal sludge (NS) (high DO operation, about 4.0 mg/L) and to obtain a comprehensive insight into the behaviours of filamentous bacteria in MBRs. Test results showed that the MBR with bulking sludge (BS-MBR) exhibited a better filtration performance and a reduced membrane fouling compared to the MBR with normal sludge (NS-MBR). It was found that the mitigation of membrane fouling by the abundant filamentous bacteria in the BS-MBR could be attributed to the larger PSD, lower hydrophobic contents in SMP, and the retention effects of a special fouling layer induced by filamentous bacteria.

11/01280 Enhancement of bioenergy production and effluent quality by integrating optimized acidification with submerged anaerobic membrane bioreactor

Jeong, E. *et al. Bioresource Technology*, 2010, 101, (S1), S7–S12.

To ensure effluent quality in the treatment of high-strength organic waste and enhance CH_4 production, this study investigates the applicability of process optimization and a submerged anaerobic membrane bioreactor (SAMBR) for a two-phase anaerobic digestion (TPAD) system. The use of response surface methodology (RSM) suggests that the optimum conditions for maximum volatile fatty acids (VFA) production were a hydraulic retention time (HRT) of 2.01 days and a substrate concentration of 29.30 g/L based on chemical oxygen demands (COD). A confirmation experiment showed that an empirical model could predict a VFA increase of 76% under the proposed conditions with a relative error of 4%. SAMBRs could convert the VFA in acidogenic effluent to CH_4 with an average production rate of 0.28 $m^3/m^3/d$ in an HRT of 14 days. All of the SAMBRs could achieve COD removal rates of over 99% by the increased solid retention time and secondary membrane formation.

11/01281 Enhancing biohydrogen production through sewage supplementation of composite vegetable based market waste

Mohanakrishna, G. *et al. International Journal of Hydrogen Energy*, 2010, 35, (2), 533–541.

The function of domestic sewage supplementation as co-substrate with composite vegetable based market waste was studied during the process of fermentative hydrogen (H_2) production. Significant improvement in H_2 production and substrate degradation were noticed upon supplementing the waste with domestic sewage. Maximum H_2 production (cummulative) was observed at 5.2 kg COD/m^3 with pulp operation and 4.8 kg COD/m^3 with non-pulp operation accounting for improvement of 51 and 55% respectively after sewage supplementation. Substrate degradation was also found to improve with respect to both carbohydrates [8% (with pulp); 5% (non-pulp)] and chemical oxygen demand [COD, 12% (with pulp); 13% (non-pulp)] after adding domestic sewage. Specific H_2 yield improved especially at lower concentrations. Supplementation of waste with co-substrate helps to maintain good buffering microenvironment supports fermentation process and in addition provides micro-nutrients, organic matter and microbial biomass. Variation in the outlet pH was less in supplementation experiments compared to normal operation.

11/01282 Esterification of used vegetable oils using the heterogeneous WO_3/ZrO_2 catalyst for production of biodiesel

Park, Y.-M. *et al. Bioresource Technology*, 2010, 101, (S1), S59–S61.

Tungsten oxide zirconia, sulfated zirconia and Amberlyst-15 were examined as a catalyst for a conversion of used vegetable oils (VOs) to fatty acid methyl esters (FAMEs). Among them, tungsten oxide zirconia was a promising heterogeneous catalyst for the production of biodiesel fuels from used VOs because of high activity in the conversion over 93% and no leaching WO_3 in the esterification reaction. The reaction conditions were optimized. A study for optimizing the reaction parameters such as the reaction temperature, stirring speed, WO_3 loading over ZrO_2 and reaction time, was carried out. The catalyst was characterized by BET, XRD, FT-IR, and NH_3-TPD. With increasing WO_3 loading over ZrO_2, the triclinic phase of WO_3 increased and the tetragonal phase of zirconia was clearly generated. The highest acid strength of 20 wt% tungsten oxide zirconia catalyst was confirmed by NH_3-TPD analysis and the result was correlated to the highest catalytic activity of the esterification reaction.

11/01283 Experimental investigation of an automotive air-conditioning system driven by a small biogas engine

Damrongsak, D. and Tippayawong, N. *Applied Thermal Engineering*, 2010, 30, (5), 400–405.

This research study investigates the use of a small biogas engine to drive a automotive vapour-compression air-conditioning system. The engine used is single-cylinder, four-stroke gasoline engine with capacity of 125 cm^3 and compression ratio of 11:1. The biogas engine can be used to run the air-conditioning system with acceptable operation over a range of speeds and loads. The modular system can operate at a range of cooling loads above 3.5 kW at high coefficient of performance, with the proper speed ratio between the engine and the compressor. Overall primary energy ratio of the modular refrigeration system driven by the biogas engine was found to be maximum at about 1.0–1.2. The performance of the modular system tends to decrease with an increase in engine speed.

11/01284 Experimental investigation of jojoba as a renewable energy source

Al-Widyan, M. and Al-Muhtaseb, M. A. *Energy Conversion and Management*, 2010, 51, (8), 1702–1707.

This work examined jojoba (oil and cake) as possible alternative fuel sources. Jojoba is a shrub that grows very well in deserts and its cake is the solid part produced upon processing of the jojoba seeds for oil extraction. In this study, pure jojoba oil and 50/50 blends with diesel fuel were tested as fuels in a single cylinder diesel engine. The diesel fuel was the baseline of comparison throughout the runs. The cake was tested for both direct combustion (pellets) and as a substrate for biogas production. The pellets were formed by compacting the cake in cylindrical dies using a hydraulic press while the biogasification was conducted in an anaerobic digester model Bioflo 110 from Brunswick. The findings indicate that the optimum injection pressure for jojoba oil in the engine is 210 bars at which engine speed was maximum (2700 rpm), NO_x and CO emissions as well as exhaust temperature were minimum. Using jojoba cake for biogasification resulted in a yield of about 600 ml biogas per 400 g of jojoba cake. Burning jojoba compacted cake (pellets) for direct combustion in a stove indicated that jojoba cake sustained a temperature in excess of 300 °C for a reasonable amount of time and that the cake was very competitive to wood and has energy content more than most types of wood. Overall, it may be stated that both jojoba oil and cake hold real promise as alternative energy sources.

11/01285 Hybrid poplar growth in bioenergy production systems: biomass prediction with a simple process-based model (3PG)

Amichev, B. Y. *et al. Biomass and Bioenergy*, 2010, 34, (5), 687–702.

Establishing short-rotation tree plantations for bioenergy and fibre production on agricultural land (abandoned farmland) would provide significant environmental and economic benefits for rural communities and society as a whole. Walker hybrid poplar (*Populus deltoides* × *P. nigra*) is one of the most commonly used varieties cultivated in Saskatchewan, Canada; however, there are no existing hybrid poplar growth models in the literature. The aim of this work was to parameterize and evaluate the 3PG model (physiological principles in predicting growth) to predict Walker tree growth in the climate and soils of Saskatchewan. The authors used annual data from Walker poplar trials (4–11-year-old stands) established at three spacing levels (2.4, 3.0 and 3.7 m) at three sites located in central Saskatchewan, Hnr, BH and ML sites. The data were split into two sets – the modelling set from the Hnr site was used to parameterize 3PG, and the testing sets from the BH and ML sites were used to evaluate Walker growth predictions made by 3PG. The bias, sum (predicted minus observed) divided by number of observations, for tree height predictions ranged from −1.76 to 1.45 m, and bias for diameter at breast height (DBH)

ranged from −2.61 to 0.66 cm. Regression R-square values of 3PG-predicted versus observed height and DBH ranged from 0.75 to 0.98. Results indicate that, once parameterized, 3PG could predict Walker hybrid poplar growth with desirable accuracy by only utilizing commonly available soils and climate data for marginal or more productive agricultural land across Saskatchewan.

11/01286 Integrated design and evaluation of biomass energy system taking into consideration demand side characteristics

Ren, H. *et al. Energy*, 2010, 35, (5), 2210–2222.

In this paper, a linear programming model has been developed for the design and evaluation of a biomass energy system, while taking into consideration demand side characteristics. The objective function to be minimized is the total annual cost of the energy system for a given customer equipped with a biomass combined cooling, heating and power (CCHP) plant, as well as a backup boiler fuelled by city gas. The results obtained from the implementation of the model demonstrate the optimal system capacities that customers could employ given their electrical and thermal demands. As an illustrative example, an investigation addresses the optimal biomass CCHP system for a residential area located in Kitakyushu Science and Research Park, Japan. In addition, sensitivity analyses have been elaborated in order to show how the optimal solutions would vary due to changes of some key parameters including electricity and city gas tariffs, biogas price, electricity buy-back price, as well as carbon tax rate.

11/01287 Kalsilite based heterogeneous catalyst for biodiesel production

Wen, G. *et al. Fuel*, 2010, 89, (8), 2163–2165.

Kalsilite ($KAlSiO_4$) was used as a heterogeneous catalyst for transesterification of soybean oil with methanol to biodiesel. Kalsilite showed relatively low catalytic activity for transesterification reaction. The catalytic activity of this catalyst was significantly enhanced by introducing a small amount of lithium nitrate by the impregnation method. A biodiesel yield of 100% and a kinematic viscosity of 3.84 cSt were achieved at a mild temperature of only 120 °C over this lithium modified kalsilite catalyst (2.3 wt% Li).

11/01288 Maximizing the solar to H_2 energy conversion efficiency of outdoor photobioreactors using mixed cultures

Berberoğlu, H. and Pilon, L. *International Journal of Hydrogen Energy*, 2010, 35, (2), 500–510.

A numerical study is presented aiming to maximize the solar to hydrogen energy conversion efficiency of a mixed culture containing microorganisms with different radiation characteristics. The green algae *Chlamydomonas reinhardtii* CC125 and the purple non-sulfur bacteria *Rhodobacter sphearoides* ATCC 49419 are chosen for illustration purposes. The previously measured radiation characteristics of each microorganism are used as input parameters in the radiative transport equation for calculating the local spectral incident radiation within a flat panel photobioreactor. The specific hydrogen production rate for each microorganism as a function of the available incident radiation is recovered from data reported in the literature. The results show that for mono-cultures, the solar to H_2 energy conversion efficiency, for all combinations of microorganism concentrations and photobioreactor thicknesses, fall on a single line with respect to the optical thickness of the system. The maximum solar energy conversion efficiency of mono-cultures of *C. reinhardtii* and *R. spaheroides* are 0.061 and 0.054%, respectively, corresponding to optical thicknesses of 200 and 16, respectively. Using mixed cultures, a total conversion efficiency of about 0.075% can be achieved corresponding to an increase of about 23% with respect to that of a mono-culture of *C. reinhardtii*. It has been shown that the choice of microorganism concentrations for maximum solar energy conversion efficiency in mixed cultures is non-trivial and requires careful radiation transfer analysis coupled with H_2 production kinetics taking into account the photobioreactor thickness.

11/01289 Modelling gas–liquid VOCs transport in two-liquid phase partitioning bioreactors

Bordel, S. *et al. International Journal of Heat and Mass Transfer*, 2010, 53, (5–6), 1139–1145.

A mechanistic model capable to accurately describe the mass transport of hexane in a two-liquid phase partitioning bioreactor (TLPB) constructed with silicone oil was developed. This work constitutes the first step in the development of simple and reliable models for the mathematical description of the off-gas treatment of volatile organic contaminants in TLPBs. The model (based on general mass balances and transport equations over off-gas rising bubbles) predicted a negative linear relationship between the fraction of organic phase and the logarithm of the pollutant fraction that remains in the gas phase. The average relative errors of the model predictions were lower than 7%. Under the tested range of operational conditions (organic phase fractions and stirring rates ranging from 5% to 30% and from 100 to 300 rpm, respectively) the maximum hexane fraction transferred from the gas to the liquid (aqueous + organic) phase increased at increasing stirring rates and silicone oil fractions up to 200 rpm and 20%, respectively. In addition, the proposed modelling approach quantified the proximity of the dispersion to thermodynamic equilibrium conditions, predicting thus the degree of mixing in the systems.

11/01290 Optimal location of lignocellulosic ethanol refineries with polygeneration in Sweden

Leduc, S. *et al. Energy*, 2010, 35, (6), 2709–2716.

The integration of ethanol production with combined heat and power plants is considered in this paper. An energy balance process model has been used to generate data for the production of ethanol, electricity, heat and biogas. The geographical position of such plants becomes of importance when using local biomass and delivering transportation fuel and heat. An optimization model has thus been used to determine the optimal locations for such plants in Sweden. The entire energy supply and demand chain from biomass outtake to gas stations filling is included in the optimization. Input parameters have been studied for their influence on both the final ethanol cost and the optimal locations of the plants. The results show that the biomass cost, biomass availability and district heating price are crucial for the positioning of the plant and the ethanol to be competitive against imported ethanol. The optimal location to set up polygeneration plants is demonstrated to be in areas where the biomass cost is competitive and in the vicinity of small to medium size cities. Carbon tax does not influence the ethanol cost, but solicits the production of ethanol in Sweden, and changes thus the geography of the plant locations.

11/01291 Optimal placement and sizing from standpoint of the investor of photovoltaics grid-connected systems using binary particle swarm optimization

Gómez, M. *et al. Applied Energy*, 2010, 87, (6), 1911–1918.

This paper introduces a binary particle swarm optimization based method to accomplish optimal location and size of a photovoltaics grid-connected system (PVGCS) for distributed power generation. The main technical constraint is the maximum installed peak power, which is limited for utilities power distributor company. The fitness function to be optimized is the profitability index. A fair comparison between the proposed algorithm and other methods is performed. For such goal, convergence curves of the average profitability index versus number of iterations are computed. The proposed algorithm reaches a better solution than genetic algorithms when considering similar computational cost (similar number of evaluations).

11/01292 Optimization of biomass production with enhanced glucan and dietary fibres content by *Pleurotus ostreatus* ATHUM 4438 under submerged culture

Papaspyridi, L.-M. *et al. Biochemical Engineering Journal*, 2010, 50, (3), 131–138.

This work was aimed at optimizing biomass production by the edible basidiomycete *Pleurotus ostreatus* ATHUM 4438 in a submerged process with enhanced glucan and dietary fibres content. β-Glucan from *Pleurotus* sp. (pleuran) has been used as food supplements due to its immunosuppressive activity. Like other dietary fibre components, oyster mushroom polysaccharides can stimulate the growth of colon microorganisms (probiotics), i.e. act as prebiotics. The FF MicroPlate was used for substrate utilization and growth monitoring. The pattern of substrate catabolism forms a substrate assimilation fingerprint which is useful in selecting media components for media optimization of maximum biomass production. Different carbon sources (95) were used and then eight of them were tested in shake flask cultures. The effect of various organic and complex nitrogen sources on biomass production was also examined and response surface methodology based on central composite design was applied to explore the optimal medium composition. When the optimized culture medium was tested in a 20-L stirred tank bioreactor, using 57 g L^{-1} xylose and 37 g L^{-1} corn steep liquor, high yields (39.2 g L^{-1}) of dry biomass was obtained. The yield coefficients for total glucan and dietary fibres on mycelial biomass formed were 140 ± 4 and 625 ± 9 mg g^{-1} mycelium dry weight, respectively.

11/01293 Optimization of ultrasonic-assisted heterogeneous biodiesel production from palm oil: a response surface methodology approach

Salamatinia, B. *et al. Fuel Processing Technology*, 2010, 91, (5), 441–448.

The use of ultrasonic processor in the heterogeneous transesterification of palm oil for biodiesel production has been investigated. Response surface methodology was employed to statistically evaluate and optimize the biodiesel production process catalysed by two alkaline earth metal oxide catalysts, i.e. BaO and SrO. SEM, surface analysis, AAS analysis and the Hammett indicator methods were used for characterization of the catalysts. Four different variables including reaction time (10–60 min), alcohol to oil molar ratio (3:1–15:1), catalyst

loading (0.5–3.0 wt%) and ultrasonic amplitude (25–100%) were optimized. Mathematical models were developed and used to predict the behaviour of the process. The models were able to accurately predict the biodiesel yield with less than 5% error for both catalysts. The basic strength of the catalysts was the main reason of their high activities. This study confirmed that the ultrasonic significantly improved the process by reducing the reaction time to less than 50 min and the catalyst loading to 2.8 wt% to achieve biodiesel yields of above 95%. The optimum alcohol to oil ratio was found to be at 9:1 while the best amplitudes were ~70 and ~80% for the BaO and SrO catalysts, respectively.

11/01294 Options to reduce the environmental impacts of residential buildings in the European Union – potential and costs

Nemry, F. *et al. Energy and Buildings*, 2010, 42, (7), 976–984.

A typology of buildings representative of the building stock for the EU-25 was developed characterizing 72 building types in terms of their representativity, geographical distribution, size, material composition, and thermal insulation. The life cycle impacts of the building types were calculated for different environmental impact categories both at building and EU-25 level. The use phase of buildings, dominated by the energy demand for heating is by far the most important life cycle phase for existing and new buildings. The environmental impacts were allocated to single building elements. Ventilation, heat losses through roofs and external walls are important for a majority of single- and multi-family houses. Three improvement options were identified: additional roof insulation, additional façade insulation and new sealings to reduce ventilation. The measures yield a significant environmental improvement potential, which, for a majority of the buildings types analyse represent at least 20% compared to the base case. The major improvement potentials at EU-level lie with single-family houses, followed by multi-family houses. Smaller reductions are expected for high-rise buildings due to the smaller share in the overall building stock. For both roof insulation and reduced ventilation, the measures were shown to be economically profitable in a majority of buildings.

11/01295 Oxygenated compounds derived from glycerol for biodiesel formulation: influence on EN 14214 quality parameters

Melero, J. A. *et al. Fuel*, 2010, 89, (8), 2011–2018.

The methyl esters of fatty acids (biodiesel) obtained via transesterification of vegetable oils or animal fats are an alternative to current fossil fuels. A large amount of glycerol as a by-product is generated in this process and new applications for this surplus need to be found. Thus, the transformation of glycerol into branched oxygen-containing compounds could be an interesting solution to provide an outlet for increasing glycerol stocks. In this work, several oxygenated compounds, obtained by transformation of glycerol via etherification, esterification and acetalization, have been assessed as components for biodiesel formulation. Different quality parameters have been evaluated following the procedures listed in the EN 14214 European Standard for biodiesel specifications. These parameters have been correlated with the amount and chemical nature of oxygenated derivate present in the biodiesel. The best performance as component for biodiesel formulation has been achieved by the mixture of ethers produced via etherification of glycerol with isobutylene. The addition of these compounds has not only improved the low-temperature properties of biodiesel (i.e. pour point and cold filter plugging point) and viscosity, but also did not impair other important biodiesel quality parameters analysed. Although most of the studied oxygenated derivates do not significantly improve any biodiesel property, they do not exert a significant negative effect either. Furthermore, all of them allow an enhancement of overall yield in the biodiesel production. Nevertheless, further improvement could be addressed with a better purification to reduce the presence of non-desired impurities such as di-isobutylenes and unreacted acetic acid, which have a negative influence especially in acid number and oxidation stability.

11/01296 Potential of biomass residues for energy production and utilization in a region of Portugal

Fernandes, U. and Costa, M. *Biomass and Bioenergy*, 2010, 34, (5), 661–666.

This article concentrates on the evaluation of the potential of biomass residues, both forest and agricultural residues, for energy production and utilization in a region of Portugal (Marvão). Marvão has been identified as an excellent region for the installation of small-scale biomass plants for heating purposes given the relatively high potential of biomass residues that it presents. The assessment of the potential of the biomass residues was carried out using geographical information systems (GIS) database and statistical analysis. It was concluded that the annual biomass residues potential for Marvão is about 10,600 tonnes, which corresponds to an energy production potential of about 106,000 GJ per annum. In addition, to illustrate the potential of biomass residues for energy utilization in the region of Marvão, the heating system of a hotel located in Marvão village has been analysed as a case study. It was concluded that the conversion of the existing fossil fuel-based heating system to a biomass-based system would have economical and environmental advantages for local investors.

11/01297 Preparation and characterization of PSSA/PVA catalytic membrane for biodiesel production

Zhu, M. *et al. Fuel*, 2010, 89, (9), 2299–2304.

Poly(styrene sulfonic acid) (PSSA)/poly(vinyl alcohol) (PVA) blend membranes prepared by the solution casting were employed as heterogeneous acid catalysts for biodiesel production from acidic oil obtained from waste cooking oil (WCO). The membranes were annealed at different temperature in order to enhance their stability. The structure and properties of the membranes were investigated by means of Fourier transform infrared spectroscopy (FTIR), thermogravimetry (TG), X-ray diffraction (XRD). It is found that the crosslinking structure among PVA and PSSA chains formed when the thermal treatment temperature was higher than 80 °C. The retention of PSSA in the blend membranes in the methanol/water solvent was markedly increased from 50% to 85% with the increase of the annealing temperature from room temperature (for the untreated membrane) to 150 °C due to the formation of the crosslinking structure. The results of esterification of acidic oil show that the conversion was slightly improve with the PVA content in the membrane at a fixed PSSA content. The thickness of the catalytic membrane had no significant effect on the conversion in the end. The membrane annealed at 120 °C exhibited the best catalytic performance among the membranes, with a stable conversion of 80% with the runs.

11/01298 Process intensification technologies in continuous biodiesel production

Qiu, Z. *et al. Chemical Engineering and Processing: Process Intensification*, 2010, 49, (4), 323–330.

As an alternative fuel biodiesel has been accepted because it is produced from renewable resources. There are some technical challenges facing biodiesel production via transesterification including long residence times, high operating cost and energy consumption, and low production efficiency. In recent years studies on biodiesel synthesis have focused on the development of process intensification technologies to resolve some of these issues. This contribution will present a brief review of some of technologies being developed and includes description of some of the types of novel reactors and relevant coupled reaction/separation processes. These technologies enhance reaction rate, reduce molar ratio of alcohol to oil and energy input by intensification of mass transfer and heat transfer and *in situ* product separation, and thus achieve continuous product in a scalable unit. Some of these technologies have been commercially successful.

11/01299 Production of ethyl ester from esterified crude palm oil by microwave with dry washing by bleaching earth

Suppalakpanya, K. *et al. Applied Energy*, 2010, 87, (7), 2356–2359.

The production of ethyl ester from a feed material of esterified crude palm oil with 1.7 wt% of free fatty acid (FFA) content using microwave heating was investigated. Parametric studies were carried out to investigate the optimum conditions for the transesterification process (amount of ethanol, amount of catalyst and reaction time). As a result, optimum reaction parameters for the transesterification process aided by microwave heating have been identified: a molar ratio of oil to ethanol of 1:8.5, 1.5 wt% of KOH/oil, a reaction time of 5 min and a microwave power of 70 W. Glycerin from the ester phase was separated by adding 10 wt% of pure glycerin. The ethyl ester was purified with 1.2 wt% of bleaching earth to remove the residual catalyst and residual glycerin. This transesterification process provided a yield of 85 wt% with an ester content of 98.1 wt%. The final ethyl ester product met the specifications stipulated by ASTM D6751–02.

11/01300 Progress in biodiesel processing

Balat, M. and Balat, H. *Applied Energy*, 2010, 87, (6), 1815–1835.

Biodiesel is a notable alternative to the widely used petroleum-derived diesel fuel since it can be generated by domestic natural sources such as soybeans, rapeseeds, coconuts, and even recycled cooking oil, and thus reduces dependence on diminishing petroleum fuel from foreign sources. The injection and atomization characteristics of the vegetable oils are significantly different than those of petroleum-derived diesel fuels, mainly as the result of their high viscosities. Modern diesel engines have fuel-injection system that is sensitive to viscosity change. One way to avoid these problems is to reduce fuel viscosity of vegetable oil in order to improve its performance. The conversion of vegetable oils into biodiesel is an effective way to overcome all the problems associated with the vegetable oils. Dilution, micro-emulsification, pyrolysis, and transesterification are the four techniques applied to solve the problems encountered with the high fuel viscosity. Transesterification is the most common method and leads to monoalkyl esters of vegetable oils and fats, now called biodiesel when used for fuel

purposes. The methyl ester produced by transesterification of vegetable oil has a high cetane number, low viscosity and improved heating value compared to those of pure vegetable oil which results in shorter ignition delay and longer combustion duration and hence low particulate emissions.

11/01301 Resource use efficiency and environmental performance of nine major biofuel crops, processed by first-generation conversion techniques

de Vries, S. C. *et al. Biomass and Bioenergy*, 2010, 34, (5), 588–601.

The authors compared the production–ecological sustainability of biofuel production from several major crops that are also commonly used for production of food or feed, based on current production practices in major production areas. The set of nine sustainability indicators focused on resource use efficiency, soil quality, net energy production and greenhouse gas emissions, disregarding socio-economic or biodiversity aspects and land use change. Based on these nine production–ecological indicators and attributing equal importance to each indicator, biofuel produced from oil palm (South-east Asia), sugarcane (Brazil) and sweet sorghum (China) appeared most sustainable: these crops make the most efficient use of land, water, nitrogen and energy resources, while pesticide applications are relatively low in relation to the net energy produced. Provided there is no land use change, greenhouse gas emissions of these three biofuels are substantially reduced compared with fossil fuels. Oil palm was most sustainable with respect to the maintenance of soil quality. Maize (USA) and wheat (north-west Europe) as feedstock for ethanol perform poorly for nearly all indicators. Sugar beet (north-west Europe), cassava (Thailand), rapeseed (north-west Europe) and soybean (USA) take an intermediate position.

11/01302 Study of mass transfer and biocatalyst stability for the enzymatic degradation of anthracene in a two-phase partitioning bioreactor

Eibes, G. *et al. Biochemical Engineering Journal*, 2010, 51, (1–2), 79–85.

In this study the optimal experimental conditions for the degradation of a polycyclic aromatic hydrocarbon in an enzymatic two-phase partitioning bioreactor (TPPB) were investigated. The immiscible organic phase was comprised of silicone oil, acting as a pollutant reservoir for anthracene. This compound underwent degradation by the enzyme versatile peroxidase (VP) produced by the white-rot fungus *Bjerkandera adusta*. Mass transfer coefficients (k_La) and enzymatic deactivation constants (k_D) were determined in the TPPB system. The effects of operational parameters such as solvent viscosity (10, 20 and 50 cSt), agitation rate (200, 250 and 300 rpm) and addition of the non-ionic surfactant Triton X-100 (below its critical micelle concentration, CMC) on the mass transfer and enzymatic decay were investigated. It was ascertained that there was superior enzymatic stability at high values of viscosity. The addition of surfactant below CMC displayed the dual benefit of increasing mass transfer of the substrate fivefold from the organic to aqueous phase whilst also creating a protecting effect upon VP. Optimized conditions led to an 88% oxidation of anthracene after 38 h.

11/01303 Techno-economic evaluation of biogas upgrading process using CO_2 facilitated transport membrane

Deng, L. and Hägg, M.-B. *International Journal of Greenhouse Gas Control*, 2010, 4, (4), 638–646.

The biogas upgrading by membrane separation process using a highly efficient CO_2-selective polyvinylamine/polyvinylalcohol (PVAm/PVA) blend membrane was investigated by experimental study and simulation with respect to process design, operation optimization and economic evaluation. This blend membrane takes advantages of the unique CO_2 facilitated transport from PVAm and the robust mechanical properties from PVA, exhibits both high CO_2/CH_4 separation efficiency and very good stability. CO_2 transports through the water swollen membrane matrix in the form of bicarbonate. CO_2/CH_4 selectivity up to 40 and CO_2 permeance up to 0.55 m^3 (STP)/m^2 h bar at 2 bar were documented in lab with synthesized biogas (35% CO_2 and 65% CH_4). Membrane performances at varying feed pressures were recorded and used as the simulation basis in this work. The process simulation of an on-farm scale biogas upgrading plant (1000 Nm^3/h) was conducted. Processes with four different membrane module configurations with or without recycle were evaluated technically and economically, and the two-stage in cascade with recycle configuration was proven optimal among the four processes. The sensitivity of the process to various operation parameters was analysed and the operation conditions were optimized.

11/01304 The productive potentials of sweet sorghum ethanol in China

Zhang, C. *et al. Applied Energy*, 2010, 87, (7), 2360–2368.

As one of the important non-grain energy crops, sweet sorghum has attracted the attention of scientific community and decision makers of the world since decades. But insufficient study has been done about the spatial suitability distribution and ethanol potential of sweet sorghum in China. This paper attempts to probe into the spatial distribution and ethanol potential of sweet sorghum in China by ArcGIS methods. Data used for the analysis include the spatial data of climate, soil, topography and land use, and literatures relevant for sweet sorghum studies. The results show that although sweet sorghum can be planted in the majority of lands in China, the suitable unused lands for large-scale planting (unit area not less than 100 hm^2) are only as much as 78.6×10^4 hm^2; and the productive potentials of ethanol from these lands are 157.1×10^4–294.6×10^4 t/year, which can only meet 24.8–46.4% of current demand for E10 (gasoline mixed with 10% ethanol) in China (assumption of the energy efficiency of E10 is equivalent to that of pure petroleum). If all the common grain sorghum at present were replaced by sweet sorghum, the average ethanol yield of 244.0×10^4 t/year can be added, and thus the productive potentials of sweet sorghum ethanol can satisfy 63.2–84.9% of current demand for E10 of China. In general, Heilongjiang, Jilin, Inner Mongolia and Liaoning rank the highest in productive potentials of sweet sorghum ethanol, followed by Hebei, Shanxi, Sichuan, and some other provinces. It is suggested that these regions should be regarded as the priority development zones for sweet sorghum ethanol in China.

11/01305 The thermal cracking of soybean/canola oils and their methyl esters

Luo, Y. *et al. Fuel Processing Technology*, 2010, 91, (6), 613–617.

Triacyl glycerides (TGs) are naturally occurring oils produced by a significant variety of crops, microorganisms (bacteria and algae), and animals (certain fats). The diversity and prevalence of the sources of these compounds suggest that they may serve as an attractive alternative to crude oil as the feedstock for the production of transportation fuels and certain industrial chemicals – organic compounds with carbon chain lengths in the range of C_7 to C_{15}. In the present study a series of batch thermal cracking reactions was performed using soybean oil and canola oil under reaction conditions leading towards attractive yields of potentially valuable (as fuels and/or chemicals) shorter chain products. An attractive yield of alkanes and fatty acids (from oil cracking) or esters (from biodiesel) was obtained. From a parametric study reaction temperature, followed by residence time, was found to have the most significant effect. Significantly, cracking under increased pressures in a hydrogen atmosphere did not improve the yields of desirable species.

11/01306 Theoretical study of a novel solar trigeneration system based on metal hydrides

Meng, X. *et al. Applied Energy*, 2010, 87, (6), 2050–2061.

In order to utilize the low grade heat energy efficiently, the preliminary scheme of a metal hydride based combined cooling, heating and power (CCHP) system driven by solar energy and industrial waste heat was proposed, in which both refrigeration and power generation are achieved. Following a step-by-step procedure recently developed by the authors, two pairs of metal hydrides were selected for the CCHP system. The working principle of the system was discussed in detail and further design of the configuration for CCHP was conducted. Based on the cycle mentioned above, the models of energy conversion and exergy analysis were set up. The multi-element valued method was used to assess the performance of the CCHP system in a whole sense, thus the analysis of influence factors on the system performance can be carried out. The typical climate conditions of Xi'an in 2005 were taken for discussion, and the results showed that the system performance is mainly affected by the quantity of solar radiation energy. The objective of the system's optimization is to increase the exergy efficiency of the metal hydride heat pump, based on the quantity of solar radiation energy. The comparison with two different traditional types of CCHP systems proved that the novel CCHP system is superior to the traditional CCHP systems concerning the integrated performance.

11/01307 Thermodynamic optimization of biomass gasification for decentralized power generation and Fischer–Tropsch synthesis

Buragohain, B. *et al. Energy*, 2010, 35, (6), 2557–2579.

In recent years, biomass gasification has emerged as a viable option for decentralized power generation, especially in developing countries. Another potential use of producer gas from biomass gasification is in terms of feedstock for Fischer–Tropsch (FT) synthesis – a process for manufacture of synthetic gasoline and diesel. This paper reports optimization of biomass gasification process for these two applications. Using the non–stoichometric equilibrium model (SOLGASMIX), the outcome of the gasification process was assessed for different combinations of operating conditions. Four key parameters have been used for optimization, namely biomass type (sawdust, rice husk, bamboo dust), air or equivalence ratio (AR = 0, 0.2, 0.4, 0.6, 0.8 and 1), temperature of gasification (T = 400, 500, 600, 700, 800, 900 and 1000 °C), and gasification medium (air, air–steam 10% mole/mole mixture, air–steam 30%mole/mole mixture). Performance of the gasification process has been assessed with four measures, viz. molar

content of H_2 and CO in the producer gas, H_2/CO molar ratio, LHV of producer gas and overall efficiency of gasifier. The optimum sets of operating conditions for gasifier for FT synthesis are: AR = 0.2–0.4, Temp = 800–1000 °C, and gasification medium as air. The optimum sets of operating conditions for decentralized power generation are: AR = 0.3–0.4, Temp = 700–800 °C with gasification medium being air. The thermodynamic model and methodology presented in this work also presents a general framework, which could be extended for optimization of biomass gasification for any other application.

11/01308 Transesterification of palm oil on $K_yMg_{1-x}Zn_{1+x}O_3$ catalyst: effect of Mg–Zn interaction

Olutoye, M. A. and Hameed, B. H. *Fuel Processing Technology*, 2010, 91, (6), 653–659.

The Mg–Zn interaction effect of $K_yMg_{1-x}Zn_{1+x}O_3$ heterogeneous type catalyst and its performance on transesterification of palm oil have been studied using the response surface methodology and the factorial design of experiments. The catalyst was synthesized using the co-precipitation method and the activity was assessed by transesterification of palm oil into fatty acid methyl esters. The ratio of the Mg/Zn metal interaction, temperature and time of calcination were found to have positive influence on the conversion of palm oil to fatty acid methyl ester (FAME) with the effect of metal to metal ratio and temperature of calcination being more significant. The catalytic activity was found to decrease at higher calcination temperature and the catalyst type $K_2Mg_{0.34}Zn_{1.66}O_3$ with Mg/Zn ratio of 4.81 gave FAME content of 73% at a catalyst loading of 1.404 wt% of oil with molar ratio of methanol to oil being 6:1 at temperature of 150 °C in 6 h. A regression model was obtained to predict conversions to methyl esters as a function of metal interaction ratio, temperature of calcination and time. The observed activity of the synthesized catalyst was due to its synergetic structure and composition.

Geothermal energy

11/01309 An updated numerical model of the Larderello–Travale geothermal system, Italy

Romagnoli, P. *et al. Geothermics*, 2010, 39, (4), 292–313.

Larderello–Travale is one of the few geothermal systems in the world that is characterized by a reservoir pressure much lower than hydrostatic. This is a consequence of its natural evolution from an initial liquid-dominated to the current steam-dominated system. Beneath a nearly impermeable cover, the geothermal reservoir consists of carbonate-anhydrite formations and, at greater depth, by metamorphic rocks. The shallow reservoir has temperatures in the range of 220–250 °C, and pressures of about 20 bar at a depth of 1000 m, while the deep metamorphic reservoir has temperatures of 300–350 °C, and pressures of about 70 bar at a depth of 3000 m. The 3D numerical code 'TOUGH2' has been used to conduct a regional modelling study to investigate the production mechanism of superheated steam, the interactions between the geothermal field and the surrounding deep aquifers, and the field sustainability. All the available geoscientific data collected in about one century of exploration and exploitation have been used to provide the necessary input parameters for the model, which covers an area (4900 km^2) about 10 times wider than the Larderello–Travale geothermal field (400 km^2). The numerical model explains the origin of the steam extracted in about one century of exploitation and shows that, at the current level, the production is sustainable at least for the next 100 years.

11/01310 Assessing innovation in emerging energy technologies: socio-technical dynamics of carbon capture and storage (CCS) and enhanced geothermal systems (EGS) in the USA

Stephens, J. C. and Jiusto, S. *Energy Policy*, 2010, 38, (4), 2020–2031.

This study applies a socio-technical systems perspective to explore innovation dynamics of two emerging energy technologies with potential to reduce greenhouse gas emissions from electrical power generation in the USA: carbon capture and storage (CCS) and enhanced geothermal systems (EGS). The goal of the study is to inform sustainability science theory and energy policy deliberations by examining how social and political dynamics are shaping the struggle for resources by these two emerging, not-yet-widely commercializable socio-technical systems. This characterization of socio-technical dynamics of CCS and EGS innovation includes examining the perceived technical, environmental, and financial risks and benefits of each system, as well as the discourses and actor networks through which the competition for resources – particularly public resources – is being waged. CCS and EGS were selected for the study because they vary considerably with respect to their social, technical, and environmental implications and risks, are unproven at scale and uncertain with respect to cost, feasibility, and life-cycle environmental impacts. By assessing the two technologies in parallel, the study highlights important social and political dimensions of energy technology innovation in order to inform theory and suggest new approaches to policy analysis.

11/01311 Assessing temperature of riverbank filtrate water for geothermal energy utilization

Shin, J. *et al. Energy*, 2010, 35, (6), 2430–2439.

Utilization of riverbank filtrate water for heating and cooling of buildings can reduce installation costs considerably by using the existing operating facilities for water purification and supply. Changwon city, Korea, has been using riverbank filtrate water for the indoor air-conditioning at its Daesan water treatment plant since 2006. In this method, the most important factor for determining the efficiency of heating and cooling is the temperature of the filtrate water. Numerical simulation of the temperature profile of riverbank filtrate water in the Daesan plant using HydroGeoSphere shows that the primary factor in determining filtrate water temperature is the pumping rate. This is because of the proportion of the river-originated water which increases with pumping rate. It also shows that maintaining the facility operation at the current pumping rate for the next 30 years will not cause any significant change in the water temperature. However, following the new city plan to install an additional 37 wells with a six times greater pumping rate than the current system might cause about 2 °C decrease in filtrate water temperature 10 years after the extension. This temperature drop will result in a significant change from the original design in heating and cooling performance.

11/01312 Low-temperature geothermal utilization in Iceland – decades of experience

Axelsson, G. *et al. Geothermics*, 2010, 39, (4), 329–338.

Geothermal energy plays a key role in the economy of Iceland and it supplies about 89% of the space heating requirements. A large fraction of the country's district heating services (hitaveitas) use energy from low-temperature geothermal systems, which are mostly located outside the volcanic zone. Many of the geothermal district heating services have been in operation for several decades and much can be learned from their operation, in particular regarding long-term management of low-temperature geothermal resources. In most cases down-hole pumps are used, but there are examples of large-scale artesian flow still being maintained. The Reykjavík geothermal district heating service is the world's largest such service. It started operation on a small scale in 1930, and today it serves Reykjavík and surrounding communities, about 58% of the total population of Iceland. The Reykjavík district heating service utilizes three low-temperature systems. The production and response (pressure, chemistry, and temperature) histories of these systems and six other low-temperature geothermal systems are discussed. Four of the systems are very productive and reach equilibrium at constant production. Two are much less productive and do not attain equilibrium, while three are of intermediate productivity. Groundwater inflow has caused temperature decline and chemical changes in two of the systems. Several problems have faced the Icelandic low-temperature operations, such as excessive pressure drawdown caused by overexploitation, colder water inflow, and sea water incursion. None of the district heating systems has ceased operation and solutions have been found to these problems. The solutions include improving the energy efficiency of the associated heating systems, deeper and more focused drilling (e.g. directional drilling), finding new drilling targets (even new drilling areas), and injection, as well as technical solutions on the surface. The long utilization case histories provide important information pertaining to sustainable management of geothermal resources.

11/01313 Optimization of hybrid–ground coupled and air source–heat pump systems in combination with thermal storage

Pardo, N. *et al. Applied Thermal Engineering*, 2010, 30, (8–9), 1073–1077.

Ground coupled heat pumps are attractive solutions for cooling and heating commercial buildings due to their high efficiency and their reduced environmental impact. Two possible ideas to improve the efficiency of these systems are decoupling energy generation from energy distribution and combining different HVAC systems. Based on these two ideas, the authors present several HVAC configurations which combine the following equipments: a ground coupled heat pump, an air to water heat pump and a thermal storage device. These HVAC configurations are linked to an office building in a cooling dominated area in order to evaluate in these conditions the total electrical consumption of each configuration to obtain which one satisfy the thermal demand more efficiently. The results of the simulations show that the electrical energy consumption obtained when the system employs a suitable configuration is of around the 60% compared with an HVAC system driven by an air to water heat pump and around the 82% compared with an HVAC system driven by a ground coupled heat pump.

Solar energy

11/01314 Application of folded sheet metal in flat bed solar air collectors

El-Sawi, A. M. *et al. Applied Thermal Engineering*, 2010, 30, (8–9), 864–871.

In the present study the chevron pattern of fold structure produced using a recently developed continuous folding technique is considered for the first time in the application of solar air collectors. An experimental study of two types of flat bed solar air collectors, with flat plate and chevron pattern absorbers, is carried out to investigate their performance over a wide range of operating conditions. A theoretical comparison between flat plate, *v*-grooved and chevron pattern absorbers is also presented. Under the considered configurations and operating conditions, the chevron pattern absorber is found to be the most efficient and that the flat plate absorber the least efficient. The chevron pattern is found to have higher performance, reaching up to 20% improvement in thermal efficiency and an increase of 10 °C in outlet temperature at some ranges of mass flow rates.

11/01315 Daily energy planning of a household photovoltaic panel

Ammar, M. B. *et al. Applied Energy*, 2010, 87, (7), 2340–2351.

This paper puts forward an energy planning approach which offers a daily optimum management of a household photovoltaic panel generation (PVG) without using storage equipment. The approach considers the PVG of the last 10 days to estimate the one of the next day, using a neuro-fuzzy algorithm. The estimated PVG is planned according to the consumer's needs so as to use the maximum of the generated energy. The algorithm decides by means of fuzzy rules the connection times of appliances, having different powers, to the photovoltaic panel (PVP) output during the day. The decision is made on the basis of optimization criteria with respect to different user operation modes. The approach is validated on a 260 Wp PVP and a set of four appliances of 30 W, 40 W, 60 W and 75 W. The system is installed at the National Engineering School, University of Sfax (ENIS) – Tunisia. The daily energetic assessment confirms that the PVG planning makes use of the estimated available energy in between 70% and 80%.

11/01316 Development of hybrid solar-assisted cooling/heating system

Huang, B. J. *et al. Energy Conversion and Management*, 2010, 51, (8), 1643–1650.

A solar-assisted ejector cooling/heating system (SACH) was developed in this study. The SACH combines a pump-less ejector cooling system (ECS) with an inverter-type heat pump (R22) and is able to provide a stable capacity for space cooling. The ECS is driven by solar heat and is used to cool the condenser of the R22 heat pump to increase its COP and reduce the energy consumption of the compressor by regulating the rotational speed of the compressor through a control system. In a complete SACH system test run at outdoor temperature 35 °C, indoor temperature 25 °C and compressor speed 20–80 Hz, and the ECS operating at generator temperature 90 °C and condensing temperature 37 °C, the corresponding condensing temperature of the heat pump in the SACH is 24.5–42 °C, cooling capacity 1.02–2.44 kW, input power 0.20–0.98 kW, and cooling COP_c 5.11–2.50. This indicates that the use of ECS in SACH can effectively reduce the condensing temperature of the heat pump by 12.6–7.3 °C and reduce the power consumption by 81.2–34.5%. The SACH can also supply heat from the heat pump. At ambient temperature from 5 to 35 °C, the heating COP_c is in the range 2.0–3.3.

11/01317 Energetic and exergetic performances of an economical and available integrated solar storage collector based on concrete matrix

Hazami, M. *et al. Energy Conversion and Management*, 2010, 51, (6), 1210–1218.

This paper deals with an experimental study of an inexpensive integrated solar storage collector (ISSC) of total aperture area of 2 m^2, used for the providing of domestic hot water. The ISSC is characterized by an absorber matrix made up of a thin cement concrete slab which performs the function of both absorbing and storing of the solar thermal energy. Inside the concrete absorber was embedded a cooper pipe network. Outdoor experiments were carried out under varied environmental conditions for several days during three consecutive months (from November 2007 to February 2008). The experiments were carried out by measuring the climatic variables, temperatures in different parts of the collectors, and mass flow rates of water, during the test days. Based on these measurements, the behaviour of the systems was analysed by comparing exit temperatures, heat losses, and delivered useful energy. A detailed energy and exergy analysis was carried out for evaluating the thermal and optical performance, exergy losses as well as exergetic efficiency for ISSC under given operating conditions. Results shows that the integrated solar storage collector, having energetic and exergetic efficiencies of 32% and 23.5% respectively, provides acceptable stored thermal heat rate by supplying approximately 80% in domestic hot water requirements for a family composed of 5–6 persons. An economic evaluation was made considering the investment time recovery through the system. The results obtained from the ISSC system were compared with the results obtained from a high quality thermosyphon solar system composed of a flat-plate collector (with a total aperture area of 2 m^2) and its corresponding insulated storage tank (200 l), tested at the same time.

11/01318 Experimental investigation of thermal performance of solar air heater having different obstacles on absorber plates

Akpinar, E. K. and Koçyiğit, F. *International Communications in Heat and Mass Transfer*, 2010, 37, (4), 416–421.

This paper presents the results of an experimental investigation of the performance for a new flat plate solar air heater (SAH) with several obstacles (Type I, Type II, and Type III) and without obstacles (Type IV). The efficiencies, the heat gain factors and heat loss coefficients are determined for the collectors and comparisons were made among them. The experimental data along with the correlations obtained by linear regression are presented. The optimal value of efficiency was determined for the solar air heater with Type II absorbent plate in flow channel duct for all operating conditions and the collector supplied with obstacles appears significantly better than that without obstacles.

11/01319 Experimental investigation on the photovoltaic–thermal solar heat pump air-conditioning system on water-heating mode

Fang, G. *et al. Experimental Thermal and Fluid Science*, 2010, 34, (6), 736–743.

An experimental study on operation performance of photovoltaic–thermal solar heat pump air-conditioning system was conducted in this paper. The experimental system of photovoltaic–thermal solar heat pump air-conditioning system was set up. The performance parameters such as the evaporation pressure, the condensation pressure and the coefficient of performance (COP) of heat pump air-conditioning system, the water temperature and receiving heat capacity in water heater, the photovoltaic (PV) module temperature and the photovoltaic efficiency were investigated. The experimental results show that the mean photovoltaic efficiency of photovoltaic–thermal (PV/T) solar heat pump air-conditioning system reaches 10.4%, and can improve 23.8% in comparison with that of the conventional photovoltaic module, the mean COP of heat pump air-conditioning system may attain 2.88 and the water temperature in water heater can increase to 42 °C. These results indicate that the photovoltaic–thermal solar heat pump air-conditioning system has better performances and can stably work.

11/01320 Experimental investigation on the use of water-phase change material storage in conventional solar water heating systems

Al-Hinti, I. *et al. Energy Conversion and Management*, 2010, 51, (8), 1735–1740.

This paper presents an experimental investigation of the performance of water-phase change material (PCM) storage for use with conventional solar water heating systems. Paraffin wax contained in small cylindrical aluminium containers is used as the PCM. The containers are packed in a commercially available, cylindrical hot water storage tank on two levels. The PCM storage advantage is firstly demonstrated under controlled energy input experiments with the aid of an electrical heater on an isolated storage tank, with and without the PCM containers. It was found that the use of the suggested configuration can result in a 13–14 °C advantage in the stored hot water temperature over extended periods of time. The storage performance was also investigated when connected to flat plate collectors in a closed-loop system with conventional natural circulation. Over a test period of 24 h, the stored water temperature remained at least 30 °C higher than the ambient temperature. The use of short periods of forced circulation was found to have minimum effect on the performance of the system. Finally, the recovery effect and the storage performance of the PCM was analysed under open-loop operation patterns, structured to simulate daily use patterns.

11/01321 Fabrication and testing of a non-glass vacuum-tube collector for solar energy utilization

Chen, K. *et al. Energy*, 2010, 35, (6), 2674–2680.

An evacuated tubular solar collector was fabricated from acrylics for improved resistance to shattering. A plasmatron was employed to apply a thin gas-barrier coating to the surfaces of the plastic tube to prevent/alleviate gas infiltration. Experiments were conducted to investigate the effect of vacuum level on the performance of the non-glass vacuum-

tube solar collector. Inserted in the evacuated tube was a finned heat pipe for solar energy collection and heat transfer to a water tank. Time variations of temperatures on the heat pipe surface and in the water tank were recorded and analysed for different degrees of vacuum in the collector. The steady-state temperature of the non-glass collector was compared to that of a commercial glass vacuum-tube collector to assess the feasibility of the use of evacuated plastic tubes for solar energy collection. A simple analytical model was also developed to assist in understanding and analysing the transient behaviour and heat losses of the vacuum-tube solar collector.

11/01322 Optical performance of inclined south-north single-axis tracked solar panels

Li, Z. *et al. Energy*, 2010, 35, (6), 2511–2516.

To investigate optical performance of the inclined south–north single-axis (ISN-axis, in short) tracked solar panels, a mathematical procedure to estimate the annual collectible radiation on fixed and tracked panels was suggested based on solar geometry and monthly horizontal radiation. For solar panels tracking about ISN-axis, the yearly optimal tilt-angle of ISN-axis for maximizing annual solar gain was about 3° deviating from the site latitude in most of China except in areas with poor solar resources, and the maximum annual collectible radiation on ISN-axis tracked panels was about 97–98% of that on dual-axis tracked panels; whereas for ISN-axis tracked panels with the tilt-angle of ISN-axis being adjusted four times in a year at three fixed tilt-angles, the annual collectible radiation was almost close to that on dual-axis tracked panels, the optimum date of tilt-angle adjustment of ISN-axis was 23 days from the equinoxes, and the optimum tilt-angle adjustment value for each adjustment was about 22°. Compared to fixed south-facing solar panels inclined at an optimal tilt-angle, the increase in the annual solar gain due to using ISN-axis sun tracking was above 30% in the areas with abundant solar resources and less than 20% in the areas with poor solar resources.

11/01323 Optimisation of building form for solar energy utilisation using constrained evolutionary algorithms

Kämpf, J. H. and Robinson, D. *Energy and Buildings*, 2010, 42, (6), 807–814.

This study describes a new methodology for optimizing building and urban geometric forms for the utilization of solar irradiation, whether by passive or active means. For this a new evolutionary algorithm (a hybrid CMA-ES/HDE algorithm) was used to search the user-defined parameter space, within defined constraints. The fitness function, solar irradiation, is predicted using the backwards ray tracing program RADIANCE in conjunction with a cumulative sky model for fast computation. Application of this technique to three very different scenarios suggest that the new method consistently converges towards an optimal solution. Furthermore, with respect to configurations subjectively chosen to be intuitively well performing, annual irradiation is increased by up to 20%; sometimes yielding highly non-intuitive but architecturally interesting forms.

11/01324 Portable solar cooker and water heater

Badran, A. A. *et al. Energy Conversion and Management*, 2010, 51, (8), 1605–1609.

A portable solar water heater was designed, built and tested. This application of solar energy devices is particularly important for the Bedouin community, which can gain a great deal from the solar energy that is continuously available in the desert. It can be also used by campers and those who use recreation vehicles. A normal satellite dish of 150 cm diameter was used as a concentrator for solar radiation. The surface of the dish was covered with reflective aluminium foil which was used to concentrate solar energy on a cooking pot in one mode of operation. This mode was operated in two ways: one with bare pot and the other with the pot being covered with glazing by putting it inside a glass box. The device was also used in another mode of operation to heat water for domestic use by placing a specially designed solar collector in the focus. It was found that, when the device was operated in the bare cooker mode, a 7 kg of water at 20 °C was brought to a boil in 1 h. Putting the pot inside the glass box reduced the time required for boiling to 40 min and the cooking power was increased by 275%. In the collector mode, the device was able to heat 30 kg of water from 20 °C to 50 °C in 21/2 h. The highest efficiency obtained for this mode was 77% and the slope of the efficiency curve was $-10.63\ W/m^2\,°C$.

11/01325 Potential use of photovoltaic-integrated solar heat pump system in Hong Kong

Chow, T. T. *et al. Applied Thermal Engineering*, 2010, 30, (8–9), 1066–1072.

Most buildings in Hong Kong are served with electric/gas water heaters for hot water supply. With the elevated aspiration on the quality of life, an increase in hot water demand partly contributes to the escalating energy use of the city in the past decades. A photovoltaic-integrated solar heat pump (PV-SAHP) system, which can be seen as a scientific merge of the photovoltaic/thermal and solar assistant heat pump technology, is here proposed as a sustainable alternative. Numerical analysis has been carried out making use of a dynamic simulation model and the TMY weather data of Hong Kong. It was found that the proposed system with R-134a is able to achieve a yearly-average COP of 5.93 and PV output efficiency of 12.1%; the energy output is therefore considerably higher than the conventional heat pump plus PV 'side-by-side' system. Within a year, the PV-SAHP system has better performance in summer time, when the monthly average COP could reach six or higher. Hence its application potential in Hong Kong is good.

11/01326 Scale-up strategy for a combined solar photo-Fenton/biological system for remediation of pesticide-contaminated water

Zapata, A. *et al. Catalysis Today*, 2010, 151, (1–2), 100–106.

This work proposes a design strategy for an industrial combined solar photo-Fenton/aerobic biological system for the decontamination of wastewater polluted with commercial pesticides. The two possibilities (photo-Fenton/bio and Bio/photo-Fenton) of the combined system were evaluated (using different analytical tools and bioassays, mainly DOC, COD, toxicity and biodegradability) in pilot plant and the most successful was scaled-up. Photo-Fenton (20 mg/L of Fe^{2+}) was carried out in compound parabolic collectors (CPC) at an initial DOC of 500 mg/L (100 mg/L of each commercial pesticide). The biological pilot reactor was an immobilized biomass reactor (IBR) filled with polypropylene Pall Ring® supports colonized by activated sludge. The industrial plant has a total collector surface of 150 m^2, total photo reactor volume of 1060 L and the scaled-up biological treatment plant (also an IBR) consists basically of two IBRs (1230 L each). The photo-Fenton treatment at pilot plant scale was able to reduce toxicity (from 96% to 50% of inhibition) and increase biodegradability (from 50% to 95%) of the wastewater and the most suitable point for combining it with the biological treatment was after the total elimination of the active ingredients. The efficiency of the combined photo-Fenton/bio system in terms of mineralization was 94%, of which 35.5% corresponds to the AOP and 58.5% to the aerobic biological treatment. The combination Bio/photo-Fenton was not successful. The efficiency of the industrial-scale combined system (photo-Fenton/bio) was 84%, 35% corresponding to the photo-Fenton treatment and 49% to the biological stage.

11/01327 Simulation and economic optimization of a solar assisted combined ejector–vapor compression cycle for cooling applications

Vidal, H. and Colle, S. *Applied Thermal Engineering*, 2010, 30, (5), 478–486.

This paper describes the hourly simulation and optimization of a thermally driven cooling cycle assisted by solar energy. The double stage solar ejector cooling cycle is modelled using the TRNSYS-EES simulation tool and the typical meteorological year file containing the weather data of Florianópolis, Brazil. The first stage is performed by a mechanical compression system with R134a as the working fluid, while the second stage is performed by a thermally driven ejector cycle with R141b. Flat plate collectors and an auxiliary energy burner provide heat to the ejector cycle. The thermo-economical optimization is carried out with respect to the intercooler temperature and the flat plate solar collector area, for given specific costs of the auxiliary energy and electric energy, the capital cost of the collectors, ejector cooler, and the capital cost of equivalent mechanical compression cooler.

11/01328 Thermoeconomic analysis and optimization of high efficiency solar heating and cooling systems for different Italian school buildings and climates

Calise, F. *Energy and Buildings*, 2010, 42, (7), 992–1003.

The paper investigates the energetic and economic feasibility of a solar-assisted heating and cooling system (SHC) for different types of school buildings and Italian climates. The SHC system under investigation is based on the coupling of evacuated solar collectors with a single-stage $LiBr–H_2O$ absorption chiller; auxiliary energy for both heating and cooling is supplied by an electric-driven reversible heat pump. The SHC system was coupled with different types of school buildings located in three different Italian climatic zones. The analysis is carried out by means of a zero-dimensional transient simulation model, developed using the TRNSYS software; the analysis of the dynamic behaviour of the building was also included. An economic model is proposed, in order to assess the operating and capital costs of the systems under analysis. Furthermore, a parametric analysis and a subsequent mixed heuristic-deterministic optimization algorithm was implemented, in order to determine the set of the synthesis/design variables that maximize system profitability. The results are encouraging, as for the potential of energy saving. On the contrary, the SHC economic profitability can be achieved only in case of public funding policies (e.g. feed-in tariffs), as always happens for the great majority of renewable energy systems.

Wind energy

11/01329 Aerodynamic flow simulation of wind turbine: downwind versus upwind configuration

Janajreh, I. *et al. Energy Conversion and Management*, 2010, 51, (8), 1656–1663.

Large-scale wind turbines and wind farms continue to grow mounting 94.1 GW of the electrical grid capacity in 2007 and expected to reach 160.0 GW in 2010. Wind energy plays a vital role in the quest for renewable and sustainable energy as well as in reducing carbon emission. Early generation wind turbines (windmills) were used mainly for water pumping and seed grinding, whereas today they generate one-fifth of the current Denmark's electricity and will double its grid capacity reaching 12.5% in 2010. Wind energy is plentiful (72 TW estimated to be commercially viable) and clean while its intensive capital cost still impede widespread deployment. However, there are technological challenges, i.e. high fatigue load, noise emission, and meeting stringent reliability and safety standards. Newer inventions, e.g. downstream wind turbines and flapping rotor blades, are sought to enhance their performance, i.e. lower turning moments and cut-in speed and to absorb portion of the cost due to the absent of yaw mechanisms. In this work, numerical analysis of the downstream wind turbine blade is conducted. In particular, the interaction between the tower and the rotor passage is investigated. Circular cross-sectional tower and aerofoil shapes are considered in a staggered configuration and under cross-stream motion. The resulting blade static pressure and aerodynamic forces are computed at different incident wind angles and wind speeds. The computed forces are compared to the conventional upstream wind turbine. Steady state and transient, incompressible, viscous Navier–Stokes and turbulent flow analysis are employed. The k-epsilon model is utilized as the turbulence closure. The passage of the rotor blade is governed by ALE and is represented numerically as a sliding mesh against the upstream fixed tower domain.

11/01330 Analysis of the furling behavior of small wind turbines

Audierne, E. *et al. Applied Energy*, 2010, 87, (7), 2278–2292.

Furling is the dominant mechanism for over speed and power control of small wind turbines. In this paper a consistent model of the dynamics of gravity-controlled furling systems based on a Lagrangian formalism is presented. The aerodynamic forces acting on tail vane and rotor have been modelled using Xfoil and blade element momentum (BEM) theory, respectively. Due to the proximity of tail vane and rotor a model of the near-wake generated by the rotor was incorporated into the model, assuming a parabolic wake shape. The different design parameters, such as lever lengths and axis tilt angles, have been studied in a systematic manner and their impact on the wind speed values for entering and leaving the furling regime have been assessed. In the first part of the study the free-stream in-flow wind speed was fixed at a given value and the system was allowed to reach stable conditions. The steady-state values of the yaw and furling angle were recorded as a function of wind speed both for increasing and decreasing wind speed and the consequences for design choices have been discussed. In the second part, a slow variation of input wind speed was superimposed on the constant wind speed signal and the dynamic response of the system was analysed. The results of the study are thought to provide an initial roadmap for the design of furling systems.

11/01331 Auctioning wind power sites when environmental quality matters

Ciaccia, G. *et al. Energy Policy*, 2010, 38, (4), 1734–1740.

This study proposes an index that allows a public authority to order different projects for the construction of onshore wind energy plants and that explicitly takes into account their environmental quality. Wind farm projects are defined as vectors of four attributes: the technical properties of each project, its social impact, its environmental impact, and the share of earnings that proponents offer to the collectivity in compensation for the negative externalities of the wind plant. The authors define an absolute index that allows the ordering of different proposals and evaluation of the acceptability of each project, providing the monetary value of each point and inducing a truthful revelation of firms' private information. Moreover, the authors calibrate the index on the basis of data referring to wind plants in southern Italy and derive the corresponding iso-scoring curves.

11/01332 Conventional and novel control designs for direct driven PMSG wind turbines

Li, S. *et al. Electric Power Systems Research*, 2010, 80, (3), 328–338.

With the advance of power electronic technology, direct driven permanent magnet synchronous generators (PMSG) have increasingly drawn interests to wind turbine manufactures. This paper studies and compares conventional and a novel control designs for a direct driven PMSG wind turbine. The paper presents transient and steady-state models of a PMSG system in a d–q reference frame. Then, general PMSG characteristics are investigated in the rotor-flux-oriented frame. A shortage of conventional control mechanisms is studied analytically and through computer simulation. A novel direct-current based d–q vector control technique is proposed by integrating fuzzy, adaptive and traditional PID control technologies in an optimal control configuration. Comparison study demonstrates that the proposed control approach, having superior performance in various aspects, is effective not only in achieving desired PMSG control objectives but also in improving the optimal performance of the overall system.

11/01333 Economics of wind power when national grids are unreliable

van Kooten, G. C. and Wong, L. *Energy Policy*, 2010, 38, (4), 1991–1998.

Power interruptions are a typical characteristic of national grids in developing countries. Manufacturing, processing, refrigeration and other facilities that require a dependable supply of power, and might be considered a small grid within the larger national grid, employ diesel generators for backup. In this study, a stochastic simulation model of a very small grid connected to an unreliable national grid is developed to show that the introduction of wind-generated power can, despite its intermittency, reduce costs significantly. For a small grid with a peak load of 2.85 MW and diesel generating capacity of 3.75 MW provided by two diesel generators, the savings from using wind energy (based on wind data for Mekelle, Ethiopia) can amount to millions of dollars for a typical July month, or some 5.5–17.5% of total electricity costs. While wind power can lead to significant savings, the variability of wind prevents elimination of the smaller of two diesel units, although this peaking unit operates less frequently than in the absence of wind power.

11/01334 Fractional-order control and simulation of wind energy systems with PMSG/full-power converter topology

Melício, R. *et al. Energy Conversion and Management*, 2010, 51, (6), 1250–1258.

This paper presents a new integrated model for the simulation of wind energy systems. The proposed model is more realistic and accurate, considering a variable-speed wind turbine, two-mass rotor, permanent magnet synchronous generator (PMSG), different power converter topologies, and filters. Additionally, a new control strategy is proposed for the variable-speed operation of wind turbines with PMSG/full-power converter topology, based on fractional-order controllers. Comprehensive simulation studies are carried out with matrix and multilevel power converter topologies, in order to adequately assert the system performance in what regards the quality of the energy injected into the electric grid. Finally, conclusions are duly drawn.

11/01335 Intelligent approach to maximum power point tracking control strategy for variable-speed wind turbine generation system

Lin, W.-M. and Hong, C.-M. *Energy*, 2010, 35, (6), 2440–2447.

To achieve maximum power point tracking (MPPT) for wind power generation systems, the rotational speed of wind turbines should be adjusted in real time according to wind speed. In this paper, a Wilcoxon radial basis function network (WRBFN) with hill-climb searching (HCS) MPPT strategy is proposed for a permanent magnet synchronous generator (PMSG) with a variable-speed wind turbine. A high-performance online training WRBFN using a back-propagation learning algorithm with modified particle swarm optimization (MPSO) regulating controller is designed for a PMSG. The MPSO is adopted in this study to adapt to the learning rates in the back-propagation process of the WRBFN to improve the learning capability. The MPPT strategy locates the system operation points along the maximum power curves based on the dc-link voltage of the inverter, thus avoiding the generator speed detection.

11/01336 Levelling the playing field? The influence of national wind power planning instruments on conflicts of interests in a Swedish county

Bergek, A. *Energy Policy*, 2010, 38, (5), 2357–2369.

Slow and complicated wind power planning and permitting procedures have been a large obstacle for wind power diffusion in Sweden and other countries. This paper complements previous siting-oriented literature with a planning perspective on these problems. The focus is two national planning instruments implemented in Sweden in the early 2000s: a national planning target and an appointment of areas of national interest for wind power. The paper identifies different types of conflicts of interest related to wind power – in addition to the conflict between wind power as a national public interest and various local private interests – and analyses the impact of the national planning instruments on the handling of these conflicts in the land-use planning process in the County of Östergötland. The analysis shows that the planning target actually made local planning officials even more inclined to treat wind power as a private rather than a public interest

and that the method used to identify areas of national interest of wind power forced wind power to compete with the combined strengths of all other public interest. The planning instruments thus left wind power to fight an uphill battle rather than to meet other interests face-to-face on a level playing field.

11/01337 Measurement of productive efficiency with frontier methods: a case study for wind farms

Iglesias, G. *et al. Energy Economics*, 2010, 32, (5), 1199–1208.

This study measures the productive efficiency of a group of wind farms during the period 2001–2004 using the frontier methods data envelopment analysis (DEA) and stochastic frontier analysis (SFA). Taking an extensive definition of the productive process of wind electricity as a starting point, the authors obtain results which allow the identification, on the one hand, an essentially *ex ante* efficiency measure and, on the other hand, aspects of relevance for wind farm development companies (developers), technology suppliers and operators in terms of their economic impact. These results may also be of interest for regulators and other stakeholders in the sector. The implications of the simultaneous use of DEA and SFA methodologies are also discussed.

11/01338 Modelling the existing Irish energy-system to identify future energy costs and the maximum wind penetration feasible

Connolly, D. *et al. Energy*, 2010, 35, (5), 2164–2173.

In this study a model of the Irish energy-system was developed using EnergyPLAN based on the year 2007, which was then used for three investigations. The first compares the model results with actual values from 2007 to validate its accuracy. The second illustrates the exposure of the existing Irish energy-system to future energy costs by considering future fuel prices, CO_2 prices, and different interest rates. The final investigation identifies the maximum wind penetration feasible on the 2007 Irish energy-system from a technical and economic perspective, as wind is the most promising fluctuating renewable resource available in Ireland. It is concluded that the reference model simulates the Irish energy-system accurately, the annual fuel costs for Ireland's energy could increase by approximately 58% from 2007 to 2020 if a business-as-usual scenario is followed, and the optimum wind penetration for the existing Irish energy-system is approximately 30% from both a technical and economic perspective based on 2020 energy prices. Future studies will use the model developed in this study to show that higher wind penetrations can be achieved if the existing energy-system is modified correctly. Finally, these results are not only applicable to Ireland, but also represent the issues facing many other countries.

11/01339 On comparing three artificial neural networks for wind speed forecasting

Li, G. and Shi, J. *Applied Energy*, 2010, 87, (7), 2313–2320.

Wind speed forecasting is critical for wind energy conversion systems since it greatly influences the issues such as the scheduling of a power system, and the dynamic control of the wind turbine. This paper presents a comprehensive comparison study on the application of different artificial neural networks in 1-h-ahead wind speed forecasting. Three types of typical neural networks, namely, adaptive linear element, back propagation, and radial basis function, are investigated. The wind data used are the hourly mean wind speed collected at two observation sites in North Dakota. The performance is evaluated based on three metrics, namely, mean absolute error, root mean square error, and mean absolute percentage error. The results show that even for the same wind dataset, no single neural network model outperforms others universally in terms of all evaluation metrics. Moreover, the selection of the type of neural networks for best performance is also dependent upon the data sources. Among the optimal models obtained, the relative difference in terms of one particular evaluation metric can be as much as 20%. This indicates the need of generating a single robust and reliable forecast by applying a post-processing method.

11/01340 Public attitudes of wind energy in Texas: local communities in close proximity to wind farms and their effect on decision-making

Swofford, J. and Slattery, M. *Energy Policy*, 2010, 38, (5), 2508–2519.

Wind energy is now recognized as an important energy resource throughout the world. Within the USA, the state of Texas currently has the largest wind energy capacity with 8797 total megawatts and an additional 660 MW under construction. With this rapid growth, it is important to achieve a better understanding of how wind energy is being perceived by the public. This paper explores three research strands: (i) describing the environmental attitudes of a population in close proximity to a wind farm development, (ii) determining the influence that proximity has on wind energy attitudes, and (iii) determining if the not-in-my-backyard (nimby) phenomenon is appropriate for explaining human perceptions of wind energy. A survey questionnaire was developed to explore perceptions of wind energy in the region as well as general attitudes about energy and the environment. Results regarding general wind energy attitudes signify overall public support for wind energy. In addition, those living closest to the wind farm indicate the lowest levels of support, while those living farthest away indicate much stronger support. Findings support the view that the use of nimby does not adequately explain the attitudes of local wind farm opposition. Alternative explanations and planning implications are discussed with a focus on public participation and education.

11/01341 The influence of wind generation on power system reliability and the possible use of hydrogen storages

Pelacchi, P. and Poli, D. *Electric Power Systems Research*, 2010, 80, (3), 249–255.

The aim of this study is to simulate the impact of non-programmable generation sources, in particular wind farms, on the reliability of an electric power system. A probabilistic model has been implemented, to evaluate the influence of wind generation on the amount of secondary/tertiary generating reserve, required in a hydro-thermoelectric system to maintain a certain level of reliability. A case study, calibrated on the electric system of one of the largest Italian islands, shows the critical issues associated with over-generation events, basically due to an underestimation of wind production. Three possible policies, to be adopted during real-time by the independent system operator (ISO) in order to face such events, are simulated and discussed in terms of system reliability and costs for balancing operation. The use of hydrogen storages, managed by the ISO to cope with over-generation contingencies, is proposed and analysed in different scenarios of wind penetration, assessing the payback time of the storage devices also considering the economic implications of system reliability.

11/01342 Why we still don't understand the social aspects of wind power: a critique of key assumptions within the literature

Aitken, M. *Energy Policy*, 2010, 38, (4), 1834–1841.

The literature on public attitudes to wind power is underpinned by key assumptions which limit its scope and restrict the findings it can present. Five key assumptions are that: (1) The majority of the public supports wind power. (2) Opposition to wind power is therefore deviant. (3) Opponents are ignorant or misinformed. (4) The reason for understanding opposition is to overcome it. (5) Trust is key. The paper calls for critical reflection on each of these assumptions. It should not be assumed that opposition to wind power is deviant/illegitimate. Opposition cannot be dismissed as ignorant or misinformed instead it must be acknowledged that objectors are often very knowledgeable. Public attitudes and responses to wind power should not be examined in order to mitigate potential future opposition, but rather in order to understand the social context of renewable energy. Trust is identified as a key issue, however greater trust must be placed in members of the public and in their knowledge. In sum, the literature must abandon the assumption that it knows who is 'right' and instead must engage with the possibility that objectors to wind power are not always 'wrong'.

11/01343 Wind power smoothing using fuzzy logic pitch controller and energy capacitor system for improvement Micro-Grid performance in islanding mode

Kamel, R. M. *et al. Energy*, 2010, 35, (5), 2119–2129.

The need of reducing CO_2 emissions in electricity generation field for solving global warming problems has led to increase interest in micro-grids (MGs) especially the one with renewable sources such as solar and wind generations. Wind speed fluctuations cause high fluctuations in output power of wind turbine which cause fluctuations in frequency and voltages of the MG in the islanding mode and originate stability problems. In this study, a new fuzzy logic pitch controller and an energy storage ultra capacitor are proposed and developed to smooth the output power of wind turbine and enhance the performance of MGs in islanding mode. These two proposed controllers are compared with the conventional PI pitch controller, which is usually used to control wind generation system when the wind speed exceeds a rated value. Obtained results showed that the two proposed strategies are effective for the MG performance improvement during islanding mode. All models and controllers are developed using Matlab® Simulink® environment.

Others, including economics

11/01344 A criterion for selecting renewable energy processes

Searcy, E. and Flynn, P. C. *Biomass and Bioenergy*, 2010, 34, (5), 798–804.

The authors propose that minimum incremental cost per unit of greenhouse gas (GHG) reduction, in essence the carbon credit required to economically sustain a renewable energy plant, is the most appropriate social criterion for choosing from a myriad of alternatives. The application of this criterion is illustrated for four processing alternatives for straw/corn stover: production of power by direct combustion and biomass integrated gasification and combined cycle (BIGCC), and production of transportation fuel via lignocellulosic ethanol and Fischer Tropsch (FT) syndiesel. Ethanol requires a lower carbon credit than FT, and direct combustion a lower credit than BIGCC. For comparing processes that make a different form of end use energy, in this study ethanol vs. electrical power via direct combustion, the lowest carbon credit depends on the relative values of the two energy forms. When power is 70$ MW h^{-1}, ethanol production has a lower required carbon credit at oil prices greater than 600$ t^{-1} (80$ bbl^{-1}).

11/01345 A methodology for eco-efficiency evaluation of residential development at city level

Li, D. Z. *et al. Building and Environment*, 2010, 45, (3), 566–573.

Residential development provides product/service value like floor space, while at the same time it induces severe environmental impacts. This paper introduces a methodology for eco-efficiency evaluation of residential development at a city level, which links product/service value and environmental impacts together. In a manner different to previous research on environmental impacts related to the construction process of residential buildings, the proposed methodology selects the ecological footprint as an aggregate environmental indicator to represent all resources consumed and all wastes produced by residential development, while the traditional ecological footprint model of a region is improved in view of characters of residential development. Since the final and main objective of the residential development is to provide floor space, which is chosen as the indicator of product/service value herein. The proposed methodology is applied and exemplified in the eco-efficiency evaluation of residential development in three Chinese cities, Beijing, Shanghai, and Nanjing. Results derived from the proposed methodology can help policy-makers and participants in the industry to assess residential development quantitatively and roundly. They can also provide implications for the environmental management of residential development at a city level.

11/01346 A model for establishing a win–win relationship between a wood pellets manufacturer and its customers

Uran, V. *Biomass and Bioenergy*, 2010, 34, (5), 747–753.

This paper investigates the possibility of establishing a win–win relationship between a wood pellets manufacturer and its customers when the manufacturer possesses a power plant fuelled by biomass and buys wood material from forest companies. Two prerequisites must be fulfilled for this relationship. First, the price of wood pellets should be lower than the fuel currently used by potential wood pellets customers and, second, the price of wood material as a raw material for producing the wood pellets should not jeopardize the profitability of the operations of the wood pellets manufacturer, who also produces electricity from biomass and sells it to the state at the feed-in tariff price. A mathematical model has been developed for each prerequisite and applied to several examples. The results demonstrate that a win–win relation can be established in Croatia and most of the member states of the EU.

11/01347 A techno-economic evaluation of the effects of centralized cellulosic ethanol and co-products refinery options with sugarcane mill clustering

Seabra, J. E. A. *et al. Biomass and Bioenergy*, 2010, 34, (8), 1065–1078.

This work compares the calculated techno-economic performance for thermochemical and biochemical conversion of sugarcane residues, considering future conversion plants adjacent to sugarcane mills in Brazil. Process models developed by the National Renewable Energy Laboratory were adapted to reflect the Brazilian feedstock composition and used to estimate the cost and performance of these two conversion technologies. Models assumed that surplus bagasse from the mill would be used as the feedstock for conversion, while cane trash collected from the field would be used as supplementary fuel at the mill. The integration of the conversion technology to the mill enabled an additional ethanol production of 0.033 m^3 per tonne of cane for the biochemical process and 0.025 m^3 t^{-1} of cane plus 0.004 m^3 t^{-1} of cane of higher alcohols for the thermochemical process. For both cases, electricity is an important co-product for the biorefinery, but especially for biochemical conversion, with surpluses of about 50 kWh t^{-1} of cane. The economic performance of the two technologies is quite similar in terms of the minimum ethanol selling price, at 318 $ m^{-3} (United States 2007 dollars) for biochemical conversion and 329 $ m^{-3} for thermochemical conversion.

11/01348 An innovative approach for energy generation from waves

Al-Habaibeh, A. *et al. Energy Conversion and Management*, 2010, 51, (8), 1664–1668.

Sustainable energy generation is becoming increasingly important due to the expected limitations in current energy resources and to reduce pollution. Wave energy generation has seen significant development in recent years. This paper describes an innovative system for generating energy from wave power. A complete description of the system is presented including the general concept, configurations, mechanical design, electrical system, simulation techniques and expected power output of the system. The results from the hydraulic linear wave simulator, using a real wave profiles captured at a location in the UK using an ultrasound system, it was seen that a ±0.8 m wave at 10 s time period, produced a conditioned power output of approximately 22 kW at optimum load conditions for the tested three-phase 44 kW permanent magnet generator type STK500. The results indicate that this new technology could provide an efficient and low-cost method of generating electricity from waves.

11/01349 China's renewable energy policy: commitments and challenges

Wang, F. *et al. Energy Policy*, 2010, 38, (4), 1872–1878.

The passing of the renewable energy law (REL) in 2005 demonstrated China's commitment to renewable energy development. In the 3 years after the REL, China's renewable electricity capacity grew rapidly. From 2006 to 2008, China's wind capacity installation more than doubled every year for 3 years in a row. However, three facts prevent us from being optimistic about China's renewable electricity future. First, considered as a share of total capacity, renewable electricity capacity is decreasing instead of increasing. This is due simply to the rapid growth of fossil fuel capacity. Second, a significant amount of renewable generation capacity is wasted because it is not connected to the electricity grid. Finally, renewable electricity plants are running at a low level of efficiency. Based on an in-depth analysis of China's existing renewable energy policy, it is suggested that these challenges should be dealt with by introducing a market-based mandatory renewable portfolio requirement coupled with strong regulatory monitoring of grid enterprises.

11/01350 DSTATCOM with flywheel energy storage system for wind energy applications: control design and simulation

Suvire, G. O. and Mercado, P. E. *Electric Power Systems Research*, 2010, 80, (3), 345–353.

In this work the use of a distribution static synchronous compensator (DSTATCOM) coupled with a flywheel energy storage system (FESS) is proposed to mitigate problems introduced by wind generation in the electric system. A dynamic model of the DSTATCOM/FESS device is introduced and a multi-level control technique is proposed. This control technique presents one control mode for active power and two control modes for reactive power, power factor correction, and voltage control. Tests of dynamic response of the device are conducted, and performance characteristics are studied taking into consideration variations of power references. Moreover, the behaviour of the device is analysed when combined with wind generation in the electric system. The results obtained demonstrate a good performance of the model developed and of the control technique proposed as well as a high effectiveness of the device to mitigate problems introduced by wind generation.

11/01351 Energy production system management – renewable energy power supply integration with building automation system

Figueiredo, J. and Martins, J. *Energy Conversion and Management*, 2010, 51, (6), 1120–1126.

Intelligent buildings, historically and technologically, refers to the integration of four distinctive systems: building automation systems (BAS), telecommunication systems, office automation systems and computer building management systems. The increasing sophisticated BAS has become the 'heart and soul' of modern intelligent buildings. Integrating energy supply and demand elements – often known as demand-side management (DSM) – has became an important energy efficiency policy concept. Nowadays, European countries have diversified their power supplies, reducing the dependence on OPEC, and developing a broader mix of energy sources maximizing the use of renewable energy domestic sources. In this way it makes sense to include a fifth system into the intelligent building group: energy production system management. This paper presents a building automation system where the DSM is fully integrated with the building's energy production system, which incorporates a complete set of renewable energy production and storage systems.

11/01352 Evaluating the cost-effectiveness of global biochar mitigation potential

Pratt, K. and Moran, D. *Biomass and Bioenergy*, 2010, 34, (8), 1149–1158.

This paper uses marginal abatement cost curves (MACCs) to illustrate the cost-effectiveness of mitigation potential offered by biochar projects compared to other mitigation measures. Biochar projects encompass a range of technologies, from wooden kilns to large processing plants. These projects differ in their abatement potential and implicit cost per tonne of carbon mitigated. Biochar stove and kiln projects in developing nations are more cost-effective than pyrolysis plant scenarios in developed countries, and thus could abate more fossil fuel carbon emissions (up to 1.03 Gt by 2030 in Asia). Even the most expensive biochar projects rival the cost-effectiveness of other carbon negative technologies such as carbon capture and storage. Economic feasibility of all biochar projects depends on a range of factors including the price of carbon and significant ancillary benefits in terms of agricultural productivity.

11/01353 Grid-connected renewable energy source systems: challenges and proposed management schemes

Alsayegh, O. *et al. Energy Conversion and Management*, 2010, 51, (8), 1690–1693.

As a result of the world's rapid socioeconomic growth and environmental concerns, exploring diverse energy resources besides fossil fuel has become a necessity and not an optional mission. Even for the oil wealthy nations, adopting energy-mix policy has become a strategic goal that is profoundly sought. As preliminary outcome, investments in renewable energy source (RES) systems in arid region nations have taken tangible steps in planning and policy-making. RES has several appealing factors; however, most countries where regulated or vertically integrated electric power systems are the principal methods for supplying the demand are cautious. Most of the electric utilities in these countries are putting reservations on RES due to the lack of monitoring and control of these grid-connected RES systems that might contribute to the instability of the electric grid. This paper identified the challenges and concerns of grid-connected RES. Moreover, it presented possible RES interconnection management schemes for the vertically integrated electric power systems.

11/01354 Hybrid solar–wind system with battery storage operating in grid-connected and standalone mode: Control and energy management – experimental investigation

Dali, M. *et al. Energy*, 2010, 35, (6), 2587–2595.

The paper presents experimental results from the operation of a test bench constituted of a grid-connected hybrid system. This device includes wind and photovoltaic (PV) physical emulators, battery energy storage, load and a controlled interconnection to the low voltage (LV) grid. Both the wind generation unit and the PV generation unit are connected to the weak AC grid via a single phase inverter with a lead acid accumulator. The grid power inverter is suitably controlled to permit the operation of the system either interconnected to the LV grid, or in standalone mode, with a seamless transfer from the one mode to the other. The paper provides a technical description of the Hybrid system devices and of the inverter energy management, along with extensive measurement results which demonstrate the system capability to operate in the aforementioned mode.

11/01355 Maximum-power-point tracking with reduced mechanical stress applied to wind-energy-conversion-systems

González, L. G. *et al. Applied Energy*, 2010, 87, (7), 2304–2312.

This paper presents an improved maximum-power-point tracking algorithm for wind-energy-conversion-systems. The proposed method significantly reduces the turbine mechanical stress with regard to conventional techniques, so that both the maintenance needs and the medium time between failures are expected to be improved. To achieve these objectives, a sensorless speed control loop receives its reference signal from a modified perturb & observe (P&O) algorithm, in which the typical steps on the reference speed have been substituted by a fixed and well-defined slope ramp signal. As a result, it is achieved a soft dynamic response of both the torque and the speed of the wind turbine, so that the whole system suffers from a lower mechanical stress than with conventional P&O techniques. The proposed method has been applied to a wind turbine based on a permanent magnet synchronous generator operating at variable speed, which is connected to the distribution grid by means of a back to back converter.

11/01356 Multicriteria renewable energy planning using an integrated fuzzy VIKOR & AHP methodology: the case of Istanbul

Kaya, T. and Kahraman, C. *Energy*, 2010, 35, (6), 2517–2527.

The purpose of this study is twofold: first, it is aimed at determining the best renewable energy alternative for Istanbul by using an integrated VIKOR-AHP methodology. Second, a selection among alternative energy production sites in this city is made using the same approach. In the proposed VIKOR-AHP methodology, the weights of the selection criteria are determined by pairwise comparison matrices of AHP. In energy decision making problems, the judgments of decision makers are usually vague. As it is relatively difficult for decision makers to provide exact values for the criteria, the evaluation data for the alternative energy policies should be expressed in linguistic terms. In order to model this kind of uncertainty in human preferences, fuzzy logic is applied very successfully. Thus, both classical VIKOR and classical AHP procedures are performed under fuzzy environment. The originality of the paper comes from the application of the proposed integrated VIKOR-AHP methodology to the selection of the best energy policy and production site. It is found that wind energy is the most appropriate renewable energy option and Çatalca district is the best area among the alternatives for establishing wind turbines in Istanbul.

11/01357 Offshore and inshore wave energy assessment: Asturias (N Spain)

Iglesias, G. and Carballo, R. *Energy*, 2010, 35, (5), 1964–1972.

The offshore and inshore wave energy resource in Asturias (northern Spain) is studied using wave buoy data and a hindcast dataset spanning 44 years (1958–2001). Offshore average wave power and annual wave energy values are found to exceed 30 kW/m and 250 MWh/m, respectively, at 7 of the 11 study sites. This substantial resource is characterized in terms of the sea states involved. Most of the energy is provided by IV quadrant waves with significant wave heights between 2 m and 5 m and energy periods between 11 s and 13 s. After analysing the offshore resource, numerical modelling is used to investigate the inshore wave patterns. A coastal wave model is validated with wave buoy data and applied to three case studies representative of storm, winter and summer conditions. Inshore wave energy concentration areas, of interest as prospective wave farm sites, are found to occur west of Cape Vidio and on the western side of the Cape Peñas peninsula. The methodology used in this investigation may serve as a model for wave energy assessments in other regions, especially where both the offshore and inshore resources are of consequence.

11/01358 Optimization of systems with the combination of ground-source heat pump and solar collectors in dwellings

Kjellsson, E. *et al. Energy*, 2010, 35, (6), 2667–2673.

The use of ground-source heat pumps for heating and domestic hot water in dwellings is common in Sweden. The combination with solar collectors has been introduced to reduce the electricity demand in the system. In order to analyse different systems with combinations of solar collectors and ground-source heat pumps, computer simulations have been carried out with the simulation program TRNSYS. Large differences were found between the system alternatives. The optimal design is when solar heat produces domestic hot water during summertime and recharges the borehole during wintertime. The advantage is related to the rate of heat extraction from the borehole as well as the overall design of the system. The demand of electricity may increase with solar recharging, because of the increased operating time of the circulation pumps. Another advantage with solar heat in combination with heat pumps is when the boreholes or neighbouring installations are drilled so close that they thermally influence each other. This may lead to decreasing temperatures in the ground, which gives decreased performance of the heat pump and increased use of electricity. The net annual heat extraction from the ground is reduced by recharge from solar heat.

11/01359 Renewability of geothermal resources

O'Sullivan, M. *et al. Geothermics*, 2010, 39, (4), 314–320.

In almost all geothermal projects worldwide, the rate of extraction of heat energy exceeds the pre-exploitation rate of heat flow from depth. For example, current production of geothermal heat from the Wairakei–Tauhara system exceeds the natural recharge of heat by a factor of 4.75. Thus, the current rate of heat extraction from Wairakei–Tauhara is not sustainable on a continuous basis, and the same statement applies to most other geothermal projects. Nevertheless, geothermal energy resources are renewable in the long-term because they would fully recover to their pre-exploitation state after an extended shut-down period. The present paper considers the general issue of the renewability of geothermal resources and uses computer modelling to investigate the renewability of the Wairakei–Tauhara system. In particular, modelling is used to simulate the recovery of Wairakei–Tauhara after it is shut down in 2053 after 100 years of production.

11/01360 Strategies for a road transport system based on renewable resources – the case of an import-independent Sweden in 2025

Lindfeldt, E. G. *et al. Applied Energy*, 2010, 87, (6), 1836–1845.

When discussing how society can decrease greenhouse gas emissions, the transport sector is often seen as posing one of the most difficult problems. In addition, the transport sector faces problems related to security of supply. The aim of this paper is to present possible strategies for a road transport system based on renewable energy sources and to illustrate how such a system could be designed to avoid dependency on imports, using Sweden as an example. The demand-side strategies considered include measures for decreasing the demand for transport, as well as various technical and non-technical means of improving vehicle fuel economy. On the supply side, biofuels and synthetic fuels produced from renewable electricity are discussed. Calculations are performed to ascertain the possible impact of these measures on the future Swedish road transport sector. The results underline the importance of powerful demand-side measures and show that although biofuels can certainly contribute significantly to an import-independent road transport sector, they are far from enough even in a biomass-rich country like Sweden. Instead, according to this study, fuels based on renewable electricity will have to cover more than half of the road transport sector's energy demand.

11/01361 Woodfuel consumption in Scotland 2005–8
McKay, H. M. *et al. Biomass and Bioenergy*, 2010, 34, (7), 1017–1027.
Three surveys were done in 2004–2005 to assess the use of wood for energy in Scotland, UK. Businesses using more than 10,000 oven-dried tonnes (odt) $year^{-1}$ dominated the sector, accounting for 131 thousand odt (k odt) which was used mainly for co-firing and heat production in the wood-processing industry. Within the category using 1000–10,000 odt $year^{-1}$ there were four developments using a total of 6 k odt $year^{-1}$. In the smallest category 33 projects used a total of 4 k odt $year^{-1}$. Of 4000 adults surveyed 4.8% used woodfuel at home. Data from a subset of users were combined with survey information to estimate domestic woodfuel usage (52 k odt $year^{-1}$). The total 2004–2005 woodfuel use in Scotland was therefore estimated as 193 k odt $year^{-1}$. Industrial and commercial usage was resurveyed in 2006, 2007, and 2008. Total woodfuel usage increased to 306 and 324 k odt in 2006 and 2007 due to an increase in the use of pellets for co-firing and also the number of projects in the two smaller size classes. The following year saw the commissioning of a dedicated biomass power plant, increasing use of recycled wood and decreasing use of pellets. The net effect within the industrial and commercial sector was an increase in demand to 413 k odt $year^{-1}$ by spring 2008. Domestic usage was re-estimated in 2007. The number of households using woodfuel was static or decreasing slightly; an annual usage of 50 k odt was estimated. Total woodfuel usage in Scotland was estimated as 463 k odt $year^{-1}$ by spring 2008.

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Fundamental science, analysis, instrumentation

11/01362 A mathematical model for predicting the performance of a compound desiccant wheel (a model of compound desiccant wheel)
Ge, T. S. *et al. Applied Thermal Engineering*, 2010, 30, (8–9), 1005–1015.
A mathematical model for predicting the performance of novel silica gel haloid compound desiccant wheel is established. Both the gas side resistance and the solid side resistance are considered in the model. It is found that the results of this model agree better to the experiments than the results of a former model which does not take the solid side resistance into account at all. Then the model is adopted to analyse the effects of some main parameters on system performance. It is found that the compound desiccant wheel has a better performance in a climate with moderate temperature or in a climate with high humidity ratio. Then under the basic conditions for the simulations (ambient air is of 35 °C, 15 g/kg and wheel thickness of 100 mm), an angle of the regeneration section between 100° and 160°, a regeneration temperature between 80 °C and 95 °C, a flow rate of process air between 2.0 m/s and 3.5 m/s and that of regeneration air between 2.5 m/s and 3.5 m/s are recommended. Also, there exists an optimal rotation speed to achieve the maximal moisture removal, which is about 12 r/h. At last, the influences of the main parameters on optimal rotation speed are discussed.

11/01363 A thermogravimetric analysis/mass spectroscopy study of the thermal and chemical stability of carbon in the Pt/C catalytic system
Sellin, R. *et al. Carbon*, 2010, 48, (8), 2244–2254.
Vulcan XC72 carbon powder and Pt/Vulcan XC72 catalytic powder were characterized by transmission electron microscopy (TEM) and their reactivity under controlled atmospheres was studied as a function of the temperature. Under air atmosphere, production of water was detected by thermogravimetric analysis coupled with mass spectroscopy (TGA-MS) measurement at m/z 18, which evidenced that hydrogenated surface functions were present on the carbon substrate. Under argon atmosphere, the comparison of TGA-MS measurements performed at m/z 18 and m/z 44 with TEM and XRD results, together with XPS measurements, indicated that platinum surface oxides are rather $Pt(OH)_2$ than PtO or PtO_2 species. Such reactive surface species is involved in the degradation mechanism of carbon support under air and inert atmospheres. Under H_2(3%)/Ar atmosphere, hydrocarbon production coming from 'reforming' reactions of the carbon support started at very low temperatures (below 373 K). TEM images of the same catalytic powder region before and after thermal treatment at 423 K under reducing atmosphere clearly displayed consumption of the carbon substrate. The reaction products may not only affect the intrinsic properties of the support but also the catalytic properties of platinum particles: reaction products could poison the anodic catalyst.

11/01364 An integrated fuzzy regression algorithm for energy consumption estimation with non-stationary data: a case study of Iran
Azadeh, A. *et al. Energy*, 2010, 35, (6), 2351–2366.
This study presents an integrated fuzzy regression and time series framework to estimate and predict electricity demand for seasonal and monthly changes in electricity consumption especially in developing countries such as China and Iran with non-stationary data. Furthermore, it is difficult to model uncertain behaviour of energy consumption with only conventional fuzzy regression (FR) or time series and the integrated algorithm could be an ideal substitute for such cases. At First, preferred Time series model is selected from linear or non-linear models. For this, after selecting preferred auto regression moving average (ARMA) model, McLeod–Li test is applied to determine non-linearity condition. When, non-linearity condition is satisfied, the preferred non-linear model is selected and defined as preferred time series model. At last, the preferred model from fuzzy regression and time series model is selected by the Granger–Newbold. Also, the impact of data preprocessing on the fuzzy regression performance is considered. Monthly electricity consumption of Iran from March 1994 to January 2005 is considered as the case of this study. The superiority of the proposed algorithm is shown by comparing its results with other intelligent tools such as genetic algorithm and artificial neural network.

11/01365 Analytic method for thermal performance and optimization of an absorber plate fin having variable thermal conductivity and overall loss coefficient
Kundu, B. *Applied Energy*, 2010, 87, (7), 2243–2255.
The absorber of a collector receives solar energy which is delivered to the transport medium to be carried away as useful energy. During this process, temperature of the absorber plate increases and therefore, thermophysical parameters engaged to determine the thermal performance of an absorber plate varies with temperature of the plate. The present study demonstrates analytically to determine the performance of an absorber plate fin with temperature dependent both thermal conductivity and overall heat loss coefficient. The decomposition method is proposed for the solution methodology. An optimum design analysis has also been carried out. A comparative study has been executed among the present results and that of existed in the published work, and a notable difference in results has been found. Finally, unlike published work, dependency parameters on the performances and optimum design have been highlighted.

11/01366 Application of an imperialist competitive algorithm to the design of a linear induction motor
Lucas, C. *et al. Energy Conversion and Management*, 2010, 51, (7), 1407–1411.
In this paper a novel optimization algorithm based on imperialist competitive algorithm (ICA) is used for the design of a low speed single sided linear induction motor (LIM). This type of motors is used increasingly in industrial process specially in transportation systems. In these applications having high efficiency with high power factor is very important. So in this paper the objective function of design is presented considering both efficiency and power factor. Finally the results of ICA are compared with the ones of genetic algorithm and conventional design. Comparison shows the success of ICA for design of LIMs.

11/01367 Application of Chebyshev polynomials to predict phase behavior of fluids containing asphaltene and associating components using SAFT equation of state

Tabatabaei-Nejad, S. A. and Khodapanah, E. *Fuel*, 2010, 89, (9), 2511–2521.

In this work, a thermodynamic model based on statistical association fluid theory (SAFT) is developed to predict the phase behaviour of mixtures containing asphaltene contents. The SAFT equation of state is a good candidate for closing that gap between statistical mechanic models and the classical models dominated by cubic equation of state. A robust, fast and accurate computational algorithm based on Chebyshev polynomial approximation is developed to calculate the density and hence fugacity using SAFT equation of state in order to perform phase equilibrium calculations. Application of Chebyshev polynomials to approximate pressure–density function leads to an interpolation error of degree 10^{-13}. Application of the proposed algorithm to calculate density of binary systems composed of ethanol and toluene shows an average relative deviation of 0.143% in the temperature range 283.15–353.15 K and for pressures up to 45 MPa. The proposed model is developed to predict the precipitation behaviour of petroleum fluids containing asphaltene. The effect of pressure, temperature and solvent concentration on the amount of asphaltene precipitation is investigated. A good agreement with an AAD of 2.593% is observed between experimental and predicted amount of asphaltene precipitate. The model is also tested to investigate the effect of temperature and solvent concentration on asphaltene onset pressures (upper and lower). Again, an excellent agreement is observed between experimental and predicted values of the asphaltene onset pressure at different temperatures and solvent concentrations with an average 0.705% relative error. The accuracy of the proposed model is compared with WinProp software using Peng–Robinson equation of state with average 53.132% and 8.657% relative errors for the amount of asphaltene precipitate and onset pressure, respectively.

11/01368 Calculation of optimal design and ideal productivities of volumetrically lightened photobioreactors using the constructal approach

Cornet, J.-F. *Chemical Engineering Science*, 2010, 65, (2), 985–998.

This article examines the optimal design and ideal kinetic performances of volumetrically lightened photobioreactors (PBR). From knowledge models simple theoretical rules are established at first to define the optimal functioning of solar and artificially lightened PBR. The constructal approach is then used, which allows the emergence of the optimal design, or the best lighting structures assembly, in Cartesian and curvilinear geometries, with a privileged treatment for the practical case of the two-dimensional cylindrical geometry. The obtained results confirm the considerable potential of this approach that is applied here to the case of the radiant light transfer in participating and reactive media. This enables one to define clearly, from a theoretical point of view, the concept of ideal PBR (both for solar or artificial illuminations), which is demonstrated to correspond exactly in most cases to volumetrically lightened PBR, mainly for the solar DiCoFluV (Dilution Contrôlée du Flux en Volume) concept. For this last case, the results of the calculations allow maximal biomass productivities as thermodynamic limits, what can contribute to clarify a confused debate on this point. The work proposed in this article establishes guidelines to conceive more efficient large-scale PBR of any desired geometry and criteria-like volume (for artificial illumination) or surface (for solar illumination) maximum productivities and internal or external irradiation.

11/01369 Continuous precipitation polymerization of vinylidene fluoride in supercritical carbon dioxide: a model for understanding the molecular-weight distribution

Ahmed, T. S. *et al. Chemical Engineering Science*, 2010, 65, (2), 651–659.

Poly(vinylidene fluoride) (PVDF) that is synthesized by precipitation polymerization in supercritical carbon dioxide ($scCO_2$) has a bimodal molecular weight distribution (MWD) and a very broad polydispersity index under certain reaction conditions. Different models have been formulated to account for this behaviour. This paper presents a homogenous model for a continuous stirred-tank reactor that includes the change of the termination reaction from kinetic control to diffusion control as the chain length of the polymeric radicals increases, and accounts for the change in the termination rate constant with macroradical chain length in the diffusion-controlled region. The model also includes the chain transfer to polymer reaction. Comparison of the model output with experimental data demonstrates that changes of the MWD, including the development of a bimodal distribution, with such reaction conditions as monomer concentration and average residence time are successfully predicted. In addition, the model can capture the occurrence of gelation, which appears to be responsible for a region of inoperability that was observed in the polymerization experiments. The success of this homogeneous model is consistent with recent research demonstrating that the CO_2-rich phase is the main locus of polymerization for the precipitation polymerization of vinylidene fluoride and vinylidene fluoride/hexafluoropropylene mixtures in $scCO_2$, at the conditions that have been studied to date.

11/01370 Density functional theory calculation on the promotion effect of H_2 in the selective catalytic reduction of NO_x over Ag–MFI zeolite

Sawabe, K. *et al. Catalysis Today*, 2010, 153, (3–4), 90–94.

Density functional theory (DFT) calculation was used to study the hydrogen promotion effect for the selective catalytic reduction (HC-SCR) of NO_x over Ag–MFI zeolite. The nature of the bond between an Ag atom and MFI is ionic. One of the roles of hydrogen addition is to neutralize the cationic Ag atom by forming an AgH molecule. The paper proposes that the formation of a Ag_4 cluster is achieved by the AgH diffusion as follows: $2AgH + Ag\text{-}Z\text{-}Ag \rightarrow HAg_4H\text{-}Z \rightarrow Ag_4\text{-}Z + H_2$. With the presence of oxygen, the HAg_4H cluster prefers the formation of HOO^- adsorbate to the desorption of H_2. O_2 is physisorbed on the Ag_4 cluster. Thus, the HAg_4H cluster is important for the activation of oxygen. Another role of hydrogen addition is to reproduce the HAg_4H cluster from the Ag_4 cluster which is generated by the SCR reaction from $HOOAg_4H$ species. Since the time-dependent DFT (TD-DFT) calculation shows that the UV absorption bands of the HAg_4H cluster are weak, UV–vis measurements are not adequate for the study of the reaction mechanisms of HC-SCR.

11/01371 Development of web-based reliability data analysis algorithm model and its application

Hwang, S.-W. *et al. Annals of Nuclear Energy*, 2010, 37, (2), 248–255.

For this study, a database model of plant reliability was developed for the effective acquisition and management of plant-specific data that can be used in various applications of plant programs as well as in Probabilistic Safety Assessment (PSA). Through the development of a web-based reliability data analysis algorithm, this approach systematically gathers specific plant data such as component failure history, maintenance history, and shift diary. First, for the application of the developed algorithm, this study reestablished the raw data types, data deposition procedures and features of the enterprise resource planning (ERP) system process. The component codes and system codes were standardized to make statistical analysis between different types of plants possible. This standardization contributes to the establishment of a flexible database model that allows the customization of reliability data for the various applications depending on component types and systems. In addition, this approach makes it possible for users to perform trend analyses and data comparisons for the significant plant components and systems. The validation of the algorithm is performed through a comparison of the importance measure value (Fussel–Vesely) of the mathematical calculation and that of the algorithm application. The development of a reliability database algorithm is one of the best approaches for providing systemic management of plant-specific reliability data with transparency and continuity. This proposed algorithm reinforces the relationships between raw data and application results so that it can provide a comprehensive database that offers everything from basic plant-related data to final customized data.

11/01372 Effects of mass transfer laws on finite time exergy

Xia, S. J. *et al. Journal of the Energy Institute*, 2010, 83, (4), 210–216.

The problem of the maximal work that can be extracted from a system consisting of one infinite chemical potential reservoir and one subsystem is investigated in this paper. Finite time exergy is derived for the fixed duration of the process by applying optimal control theory. Effects of mass transfer laws on the finite time exergy and the corresponding optimal mass transfer processes are analysed. The optimal thermodynamic processes for the finite time exergy include two categories: one is that the chemical potential of the subsystem is a constant and the chemical potential difference between the reservoir and the subsystem is also a constant during the mass transfer process, and the other is that the chemical potential of the subsystem switches between two optimal values during the mass transfer process. Mass transfer laws have significant effects on the optimal thermodynamic process for the finite time exergy, and the necessary and sufficient condition to determine the optimal thermodynamic process is also given. The results show that the optimal thermodynamic processes with mass transfer laws $[g \propto \Delta(\mu)]$ and $[g \propto \Delta(c)]$, where $\Delta\mu$ is the chemical potential difference and Δc is the concentration difference, belong to the first category, while the optimal thermodynamic processes with mass transfer laws $g \propto [(\Delta\mu) + (\Delta\mu)^n]$, where n is an odd number and equal to or larger than 9, belong to the second category. The finite time exergy tends to the classical thermodynamic exergy when the duration tends to infinite long. The finite time exergy is a more realistic, stronger limit compared to the classical thermodynamic exergy.

11/01373 Exergy analysis as a tool for the integration of very complex energy systems: the case of carbonation/calcination CO_2 systems in existing coal power plants

Romeo, L. M. *et al. International Journal of Greenhouse Gas Control*, 2010, 4, (4), 647–654.

A common characteristic of carbon capture and storage systems is the important energy consumption associated with the CO_2 capture process. This important drawback can be solved with the analysis, synthesis and optimization of this type of energy systems. The second law of thermodynamics has proved to be an essential tool in power and chemical plant optimization. The exergy analysis method has demonstrated good results in the synthesis of complex systems and efficiency improvements in energy applications. In this paper, a synthesis of pinch analysis and second law analysis is used to show the optimum window design of the integration of a calcium looping cycle into an existing coal power plant for CO_2 capture. Results demonstrate that exergy analysis is an essential aid to reduce energy penalties in CO_2 capture energy systems. In particular, for the case of carbonation/calcination CO_2 systems integrated in existing coal power plants, almost 40% of the additional exergy consumption is available in the form of heat. Accordingly, the efficiency of the capture cycle depends strongly on the possibility of using this heat to produce extra steam (live, reheat and medium pressure) to generate extra power at steam turbine. The synthesis of pinch and second law analysis could reduce the additional coal consumption due to CO_2 capture 2.5 times, from 217 to 85 MW.

11/01374 Hybrid fuel impact reconciliation method: an integral tool for thermoeconomic diagnosis

Pacheco Ibarra, J. J. *et al. Energy*, 2010, 35, (5), 2079–2087.

This paper proposes a method of thermoeconomic diagnosis based on the concepts of the fuel impact formula and the analytical reconciliation method. Such a method is able to detect, isolate and quantify individually the causes in terms of the additional fuel consumption, when internal malfunctions or control deviations occur. Commonly, any diagnosis method requires the definition of a test state condition, a reference state condition, and a comparison technique. In the proposed method the technique is based on the reconciliation procedure, however the common factor consists in maintaining the overall production of a steady operating plant. This will determine the term-by-term fuel impact due to each malfunction. The results obtained allow a comparison between the methods mentioned earlier. The keys of the proposed method are the modification of the reference state, the integration of a modified fuel impact formula and the introduction of a filtering technique for the effects induced by the control and regulation system. In order to validate the mathematical model, this is applied to a combined cycle power plant. Comparisons between the proposed model and the results from the other two methods are studied. The diagnosis error was less than 0.2%.

11/01375 Influence of flow field on sedimentation efficiency in a circular settling tank with peripheral inflow and central effluent

Bajcar, T. *et al. Chemical Engineering and Processing: Process Intensification*, 2010, 49, (5), 514–522.

The paper presents an experimental study of suspension flow patterns and velocity field inside a circular settling tank with continuous operation. Research was focused on the impact of a specific flow pattern on the sedimentation efficiency of the prototype settling tank. The latter differed from a common circular settling tank in that it was peripherally fed and had the central draw-off. Experiment was carried out on a settling tank section made of Plexiglass and represented a radial slice of a prototype settling tank. The flow field and local suspension concentration was determined by computer-aided visualization. Sedimentation efficiency was assessed relatively by comparison of the amount of settled particles (sludge height measurements) between different types of flow in a certain time period of the settling tank operation. Results showed that there were two types of flow in the settling tank that were initiated by a horizontal or vertical inflow from the distribution ring. The type of inflow (horizontal or vertical) was a function of the suspension height in the settling tank. Significant differences in sedimentation efficiency were observed between both types of flow, particularly at lower inlet suspension concentrations. Horizontal inflow proved to be less efficient in terms of settling.

11/01376 Maximizing the lightshelf performance by interaction between lightshelf geometries and a curved ceiling

Freewan, A. A. *Energy Conversion and Management*, 2010, 51, (8), 1600–1604.

The interaction between different lightshelf geometries combined with a curved ceiling was investigated using radiance to maximize the daylight performance of a lightshelf. Two main performance parameters were investigated; illuminance level and distribution uniformity in a large space located in a sub-tropical climate region like Jordan. It was found that a curved lightshelf could improve the daylight level by 10% compared to a horizontal lightshelf. A curved lightshelf help to bounce more daylight deep into a space thus improve the illuminance level and uniformity level. The best lightshelf shapes found are curved and chamfered lightshelves compared to horizontal lightshelves.

11/01377 Potentiometric titration as a straightforward method to assess the number of functional groups on shortened carbon nanotubes

Samorì, C. *et al. Carbon*, 2010, 48, (9), 2447–2454.

The conditions for oxidizing multi-walled carbon nanotubes to shorten them to a narrow length distribution have been optimized. One of the most difficult achievements is to fully characterize this material from a chemical point of view, and to find a good quantitative correlation among different techniques. The combination of different methods to determine the number of functional groups generated during strong acid treatment and a further amidation reaction is reported. A good correlation was found using the colorimetric Kaiser test, thermogravimetric analysis and potentiometric argentometric titration. The final technique is highly versatile and, being non-destructive, allows a complete recovery of the starting material. Short carbon nanotubes are particularly useful for applications in biomedicine, and the control and precise assessment of their functionalization is critical when used as carriers for therapeutic molecules.

11/01378 Prediction of the heat transfer coefficient for ice slurry flows in a horizontal pipe

Kousksou, T. *et al. Energy Conversion and Management*, 2010, 51, (6), 1311–1318.

In this study, heat transfer for ice slurry flows was investigated. For the experiments, ice slurry was made from 9% ethanol–water solution flow in a 20 mm internal diameter, 1000 mm long horizontal copper tube. The ice slurry was heated by a cylindrical electrical resistance. Experiments of the melting process were conducted with changing the ice slurry mass flux rate and the heat flux. The enthalpy-porosity formulation was used to predict the ice slurry temperature and the local values of heat transfer coefficient in the exchanger. Measurements and data acquisition of ice slurry temperature and mass flow rate at the inlet and outlet are performed. It was found that the heat transfer rates increase with the mass flow rate, the ice fraction and the heat flux density. However, the effect of ice fraction appears not to be significant at high mass flow rates. In addition, the correlation proposed elsewhere gives good agreement with numerical results.

11/01379 Quick-E-scan: a methodology for the energy scan of SMEs

Cagno, E. *et al. Energy*, 2010, 35, (5), 1916–1926.

This paper introduces the Quick-E-Scan methodology that has been developed to achieve the operational energy efficiency of small and medium enterprises (SMEs), characterized by being scarcely disposed to long energy audits and by a limited budget for energy management programs. On one side, through dividing the firm into functional units – either service (lighting, HVAC, etc.) or production units – the main consuming areas are identified and a criticality index is defined; conversely, an enhancement index highlights the gap of each unit towards the best available techniques (BATs) in energy management programs. Finally, a priority index, created with the junction of the two indexes, points out the most profitable areas in which energy saving measures should be implemented. The methodology, particularly quick and simple, has been successfully tested in 38 SMEs in northern Italy.

11/01380 Rational approaches for combining redundant, independent measurements to minimize combined experimental uncertainty

Park, Y.-G. *et al. Experimental Thermal and Fluid Science*, 2010, 34, (6), 720–724.

General methods for combining multiple, independent measurements for minimized uncertainty are presented. Although the methods are general, the presentation is motivated by the reduction of heat exchanger performance data. It is demonstrated that the prevalent practice of using the arithmetic mean of two measured heat transfer rates for the evaluation of heat exchanger performance, which is widely adopted in the literature and used in engineering standards, does not always lead to reduced experimental uncertainty and very rarely – if ever – leads to a minimized experimental uncertainty. For the case of averaging two redundant measurements, simple criteria are developed to determine whether using the arithmetic mean or a single measurement yields a smaller absolute or relative uncertainty. Then, more general methods are proposed in the form of weighted-linear averages, in which the weight factors are determined to minimize the combined uncertainty. The methods are generally applicable to averaging any number of redundant measurements with varying uncertainties.

11/01381 Stability and growth of gas hydrates below the ice–hydrate–gas equilibrium line on the *P–T* phase diagram

Melnikov, V. P. *et al. Chemical Engineering Science*, 2010, 65, (2), 906–914.

Using a previously developed experimental technique, the behaviour of small methane and propane hydrate samples formed from water droplets between 0.25 and 2.5 mm in size has been studied in the pressure–temperature area between the ice–hydrate–gas equilibrium line and the supercooled water–hydrate–gas metastable equilibrium line, where ice is a stable phase. The unusual persistence of the hydrates within the area bounded by these lines and the isotherms at $T = 253$ K for methane hydrate or at $T = 263$ K for propane hydrates was observed. This behaviour has not previously been reported. For example, in the experiment carried out at 1.9 MPa and 268 K, the methane hydrates existed in a metastable state (the equilibrium pressure at 268 K is 2.17 MPa) for 2 weeks, then immediately dissociated into liquid supercooled water and gas after the pressure was isothermally decreased slightly below the supercooled water–hydrate–gas metastable equilibrium pressure. It was found that dissociation of metastable hydrate into supercooled water and gas was reversible. The lateral hydrate film growth rates of metastable methane and propane hydrates on the surface of supercooled water at a pressure below the ice–hydrate–gas equilibrium pressure were measured. The temperature range within which supercooled water formed during hydrate dissociation can exist and a role of supercooled water in hydrate self-preservation is discussed.

11/01382 Theoretical efficiency limits for energy conversion devices

Cullen, J. M. and Allwood, J. M. *Energy*, 2010, 35, (5), 2059–2069.

Using energy more efficiently is a key strategy for reducing global carbon dioxide emissions. Due to limitations on time and resources, actions must be focused on the efficiency measures which will deliver the largest gains. Current surveys of energy efficiency measures assess only known technology options developed in response to current economic and technical drivers. However, this ignores opportunities to deliver long-term efficiency gains from yet to be discovered options. In response, this paper aims to calculate the absolute potential for reducing energy demand by improving efficiency, by finding the efficiency limits for individual conversion devices and overlaying these onto the global network of energy flow. The potential efficiency gains for each conversion device are found by contrasting current energy demand with theoretical minimum energy requirements. Further insight is gained by categorizing conversion losses according to the underlying loss mechanisms. The result estimates the overall efficiency of global energy conversion to be only 11%; global demand for energy could be reduced by almost 90% if all energy conversion devices were operated at their theoretical maximum efficiency.

11/01383 Theoretical study of hydrogen flow in porous medium of local Sweileh Sand

Al Asfar, J. J. *et al. Energy Conversion and Management*, 2010, 51, (8), 1727–1734.

The hydrogen flow in Sweileh sand porous material was studied theoretically. The flow characteristics such as temperature, pressure, density and velocity profiles were calculated by solving the governing equations of two-dimensional compressible flow in solid porous media. These equations include continuity, momentum and energy, which were solved using finite volume method incorporated in a computer code. It was found that Sweileh sand may be used as a solid medium for hydrogen storage with competitive storing capacity when compared with typical metal hydride storing capacity.

11/01384 Three-dimensional study of heat and fluid flow of air and dielectric liquids filling containers partially heated from below and entirely cooled from above

Ben-Cheikh, N. *et al. International Communications in Heat and Mass Transfer*, 2010, 37, (5), 449–456.

In this work, a numerical procedure based on the finite volume method coupled with a full multigrid acceleration is utilized to study three-dimensional flow structures and heat transfer characteristics in partially heated 3-D containers having a heated strip on the lower horizontal wall. The opposite horizontal wall is cooled to a uniform low temperature and the four remaining walls are insulated. Two different fluids, one air ($Pr = 0.7$) and the other a dielectric liquid ($Pr = 25$) are employed encompassing descriptive Rayleigh numbers Ra that range three orders of magnitude from 10^3 to 10^6. Typical plots of streamlines and isotherms are presented to analyse the circulatory flow patterns set up by the buoyancy force of the fluids. At low Ra, the flow structures and average Nusselt numbers are similar for both fluids under consideration. On the contrary, for higher Ra, a systematic comparison illuminates heat transfer augmentation when the Prandtl number is switched from air to the dielectric fluid. At high $Ra = 10^6$, the air flow ($Pr = 0.70$) becomes unsteady whereas the dielectric liquid flow ($Pr = 25$) remains steady. At the end, monomial correlations are presented for the quantification of the heat transfer that emanates from the heated bottom strip in harmony with the various Rayleigh number associated with the two dissimilar fluids.

11/01385 Understanding the scattering mechanism of single-walled carbon nanotube based gas sensors

Zhong, J. *et al. Carbon*, 2010, 48, (7), 1970–1976.

In the interaction between gas molecules with single-walled carbon nanotube (SWCNT), this paper shows that, as a result of collisions, gas scattering contributes an important background signal and should be considered in SWCNT-based gas sensors. Experimental evidence of the collision-induced tube wall deformation is demonstrated using *in situ* X-ray absorption near-edge structure spectroscopy. Results support the occurrence of the scattering process and show how gas collisions may affect the electronic structure of SWCNTs.

11/01386 Using principal component and cluster analysis in the heating evaluation of the school building sector

Gaitani, N. *et al. Applied Energy*, 2010, 87, (6), 2079–2086.

In the field of energy savings in buildings, the interest towards the school sector is deeply motivated: schools have standard energy demands and high levels of environmental comforts should be guaranteed. The University of Athens in collaboration with the school authority of Greece undertook a complete program on energy classification and environmental quality of school buildings. Data on energy consumptions were gathered and analysed with the participation of 1100 schools from all the prefectures of Greece. The data have been provided by the school authority of the country (OSK), in collaboration with the management of each school building. With regards to the size of the building and the external climate variability (HDD-method) energy normalization techniques have been applied in order to homogenize the data set. An energy classification tool has been created through clustering techniques, using the collected data regarding the heating energy consumption and as a result five energy classes have been defined. To evaluate the potential energy conservation for each class, the typical characteristics of school buildings belonging to an energy class have to be identified. A new methodology based on the use of the principal components analysis has been developed. The method allows to define in an accurate way the typical building of each energy class and thus to perform analysis on the potential energy savings for the specific group of school buildings. By reducing the dimensionality of the problem, a bidimensional graphic in the first two PCs coordinate system promotes the understanding of the correlation between the examined variables, as well as the determination of sub-groups of school buildings with similar characteristics. The typical school of seven variables sample is defined as the closest to the medians in the principal components' coordinate system.

11/01387 Wide-angle light scattering (WALS) for soot aggregate characterization

Oltmann, H. *et al. Combustion and Flame*, 2010, 157, (3), 516–522.

A novel set-up for the experimental determination of aggregate morphology in combustion processes based on elastic light scattering has been designed and realized. A key feature of this wide-angle light scattering (WALS) approach is an ellipsoidal mirror which is used to collect scattered light over a wide angular range of about 10–170°. The set-up employs a cw solid-state laser as light source and an intensified CCD-camera as detector. By means of the mirror the scattered light is imaged onto the detector allowing for a simultaneous acquisition of a full scattering diagram with a high angular resolution of about 0.6°. To demonstrate the performance of the approach, measurements for various sooting flames produced by premixed combustion in a flat flame burner were carried out, where the burner was operated with different equivalence ratios and fuels. It is shown that radii of gyration of soot particles may efficiently be obtained from an analysis of the scattering diagrams.

Fuel cell technology

11/01388 A one-dimensional, two-phase model for direct methanol fuel cells – part I: model development and parametric study

Ko, J. *et al. Energy*, 2010, 35, (5), 2149–2159.

A one-dimensional, steady-state, two-phase direct methanol fuel cell (DMFC) model is developed to precisely investigate complex physio-chemical phenomena inside DMFCs. In this model, two-phase species transport through the porous components of a DMFC is formulated based on Maxwell–Stefan multi-component diffusion equations, while capillary-induced liquid flow in the porous media is described by Darcy's equation. In addition, the model fully accounts for water and methanol crossover through the membrane, which is driven by the

effects of electro-osmotic drag, diffusion, and the hydraulic pressure gradient. The developed model is validated against readily available experimental data in the literature. Then, a parametric study is carried out to investigate the effects of the operating temperature, methanol feed concentration, and properties of the backing layer. The results of the numerical simulation clarify the detailed influence of these key designs and operating parameters on the methanol crossover rate as well as cell performance and efficiency. The results emphasize that the material properties and design of the anode backing layer play a critical role in the use of highly concentrated methanol fuel in DMFCs. The present study forms a theoretical background for optimizing the DMFC's components and operating conditions.

11/01389 Energy efficiency analysis of an integrated glycerin processor for PEM fuel cells: comparison with an ethanol-based system

Oliva, D. G. *et al. International Journal of Hydrogen Energy*, 2010, 35, (2), 709–724.

The aim of this work is to analyse energetically the use of glycerin as the primary hydrogen source to operate a proton exchange membrane fuel cell. A glycerin processor system based on its steam reforming is described departing from a previous process model developed for ethanol processing. Since about 10% w/w of glycerin is produced as a byproduct when vegetable oils are converted into biodiesel, and due to the later is increasing its production abruptly, a large glycerin excess is expected to oversaturate the market. The reformed stream contains mainly H_2 but also CO, CO_2, H_2O and CH_4. As CO is a poison for PEM fuel cell type, a stream purification step is previously required. The purification subsystem consists of two water gas shift reactors and a CO preferential oxidation reactor to reduce the CO levels below 10 ppm. The reforming process is governed by endothermic reactions, requiring thus energy to proceed. Depending on the system operation point, the energy requirements can be fulfilled by burning an extra glycerin amount (to be determined), which is the minimal that meets the energy requirements. In addition a self-sufficient operation region can be distinguished. In this context, the water/glycerin molar ratio, the glycerin steam reformer temperature, the system pressure, and the extra glycerin amount to be burned (if necessary) are the main decision variables subject to analysis. Process variables are calculated simultaneously, updating the composite curves at each iteration to obtain the best possible energy integration of the process. The highest net system efficiency value computed is 38.56% based on the lower heating value, and 34.71% based on the higher heating value. These efficiency values correspond to a pressure of 2 atm, a water/glycerin molar ratio of 5, a glycerin steam reformer temperature of 953 K, and an extra glycerin amount burned of 0.27 mol h^{-1}. Based on the main process variables, suitable system operation zones are identified. As in practice, most PEM fuel cells operate at 3 atm, optimal variable values obtained at this condition are also reported. Finally, some results and aspects on the system performance of both glycerin and ethanol processors operated at 3 atm are compared and discussed.

11/01390 Experimental measurements of effective diffusion coefficient of oxygen–nitrogen mixture in PEM fuel cell diffusion media

Zamel, N. *et al. Chemical Engineering Science*, 2010, 65, (2), 931–937.

PEM fuel cells are increasingly designed to operate at high current densities. At these densities, mass transport limitations become very significant, but they are not well understood, with many modelling studies but few experimental observations. The use of accurate transport coefficients to simulate the mass transport at high current densities is crucial. In this study, experimental measurements have been carried out to determine the effective diffusion coefficient in the carbon paper gas diffusion layer that is commonly used in PEM fuel cells. It was found that almost all the existing theoretical models significantly overpredict the effective diffusion coefficient by as much as four or five times; thus, underestimating the transport limitations considerably. Further, the effects of temperature, Teflon treatment for hydrophobicity and porosity on the effective diffusion coefficient were investigated. It was found that temperature does not affect the overall diffusibility of the gas. The diffusibility is decreased with the increase of Teflon treatment and decrease in porosity. Further work on better understanding the diffusion process in the gas diffusion layer is under way.

11/01391 Hydrogen production from formic acid in pH-stat fed-batch operation for direct supply to fuel cell

Shin, J.-H. *et al. Bioresource Technology*, 2010, 101, (S1), S53–S58.

Enterobacter asburiae SNU-1 harvested after cultivation was used as a whole cell biocatalyst, for the production of hydrogen. Formic acid was efficiently converted to hydrogen using the harvested cells with an initial hydrogen production rate and total hydrogen production of 491 ml/l/h and 6668 ml/l, respectively, when 1 g/l of whole cell enzyme was used. Moreover, new pH-stat fed-batch operation was conducted, and total hydrogen production was 1.4 times higher than that of batch operation. For practical application, bio-hydrogen produced from formic acid using harvested cells was directly applied to PEMFC for power generation.

11/01392 Influence of the rated power in the performance of different proton exchange membrane (PEM) fuel cells

San Martin, J. I. *et al. Energy*, 2010, 35, (5), 1898–1907.

Fuel cells are clean generators that provide both electrical and thermal energy with a high global efficiency level. The characteristics of these devices depend on numerous parameters such as: temperature, fuel and oxidizer pressures, fuel and oxidizer flows, etc. Therefore, their influence should be evaluated to appropriately characterize behaviour of the fuel cell, in order to enable its integration in the electric system. This paper presents a theoretical and experimental analysis of the performance of two commercial proton exchange membrane fuel cells of 40 and 1200 W, and introduces the application of the principle of geometrical similarity. Using the principle of geometrical similarity it is possible to extrapolate the results obtained from the evaluation of one fuel cell to other fuel cells with different ratings.

11/01393 Modeling of solid oxide fuel cells for dynamic simulations of integrated systems

Salogni, A. and Colonna, P. *Applied Thermal Engineering*, 2010, 30, (5), 464–477.

Solid oxide fuel cell (SOFC) stacks are at the core of complex and efficient energy conversion systems for distributed power generation. Such systems are currently in various stages of development. These power plants of the future feature complicated configurations, because the fuel cell demands for a complex balance of plant. Moreover, proposed SOFC-based systems for stationary applications are often connected to additional components and subsystems, such as a gasifier with its gas-cleaning section, a gas turbine, and a heat recovery system for thermal cogeneration or additional power production. For the simplest SOFC configurations, and more so for complex integrated systems, the dynamic operation of the power plant is challenging, especially because the fluctuating electrical load of distributed energy systems demand for reliable transient operation. Issues related to dynamic operation must be studied in the early design stage and simulation results can be used to optimize the system configuration, taking into account transient behaviour. This paper presents the development and the validation of a non-linear dynamic lumped-parameters model of a SOFC stack suitable for integration into models of complex power plants. Particular emphasis is placed on the systematic approach to model development. The model is implemented using the open-source Modelica language, which allows for a high degree of flexibility and modularity, the main features of the model herein presented. The SOFC stack model will be incorporated into ThermoPower, a freely distributed library of reusable software components for the modelling of thermo-hydraulic processes and power plants.

11/01394 Numerical study of assembly pressure effect on the performance of proton exchange membrane fuel cell

Taymaz, I. and Benli, M. *Energy*, 2010, 35, (5), 2134–2140.

The performance of the fuel cell is affected by many parameters. One of these parameters is assembly pressure that changes the mechanical properties and dimensions of the fuel cell components. Its first duty, however, is to prevent gas or liquid leakage from the cell and it is important for the contact behaviours of fuel cell components. Some leakage and contact problems can occur on the low assembly pressures whereas at high pressures, components of the fuel cell, such as bipolar plates (BPP), gas diffusion layers (GDL), catalyst layers, and membranes, can be damaged. A finite element analysis (FEA) model is developed to predict the deformation effect of assembly pressure on the single channel PEM fuel cell in this study. Deformed fuel cell single channel model is imported to three-dimensional, computational fluid dynamics (CFD) model which is developed for simulating proton exchange membrane (PEM) fuel cells. Using this model, the effect of assembly pressure on fuel cell performance can be calculated. It is found that, when the assembly pressure increases, contact resistance, porosity and thickness of the gas diffusion layer (GDL) decreases. Too much assembly pressure causes GDL to destroy; therefore, the optimal assembly pressure is significant to obtain the highest performance from fuel cell. By using the results of this study, optimum fuel cell design and operating condition parameters can be predicted accordingly.

11/01395 Performance of air-breathing direct methanol fuel cell with anion-exchange membrane

Kim, J.-H. *et al. International Journal of Hydrogen Energy*, 2010, 35, (2), 768–773.

This report details development of an air-breathing direct methanol alkaline fuel cell with an anion-exchange membrane. The commercially available anion-exchange membrane used in the fuel cell was first electrochemically characterized by measuring its ionic conductivity, and showed a promising result of 1.0×10^{-1} S cm^{-1} in a 5 M KOH

solution. A laboratory-scale direct methanol fuel cell using the alkaline membrane was then assembled to demonstrate the feasibility of the system. A high open-circuit voltage of 700 mV was obtained for the air-breathing alkaline membrane direct methanol fuel cell (AMDMFC), a result about 100 mV higher than that obtained for the air-breathing DMFC using a proton exchange membrane. Polarization measurement revealed that the power densities for the AMDMFC are strongly dependent on the methanol concentration and reach a maximum value of 12.8 mW cm^{-2} at 0.3 V with a 7 M methanol concentration. A durability test for the air-breathing AMDMFC was performed in chronoamperometry mode (0.3 V), and the decay rate was approximately 0.056 mA cm^{-2} h^{-1} over 160 h of operation. The cell area resistance for the air-breathing AMDMFC was around 1.3 Ω cm^2 in the open-circuit voltage (OCV) mode and then is stably supported around 0.8 Ω cm^2 in constant voltage (0.3 V) mode.

11/01396 Power generation efficiency of an SOFC–PEFC combined system with time shift utilization of SOFC exhaust heat
Obara, S. *International Journal of Hydrogen Energy*, 2010, 35, (2), 757–767.
A microgrid, with little environmental impact, is developed by introducing a combined SOFC (solid oxide fuel cell) and PEFC (proton exchange membrane fuel cell) system. Although the SOFC requires a higher operation temperature compared to the PEFC, the power generation efficiency of the SOFC is higher. However, if high temperature exhaust heat may be used effectively, a system with higher total power generation efficiency can be built. Therefore, this paper investigates the operation of a SOFC–PEFC combined system, with time shift operation of reformed gas, into a microgrid with 30 houses in Sapporo, Japan. The SOFC is designed to correspond to base load operation, and the exhaust heat of the SOFC is used for production of reformed gas. This reformed gas is used for the production of electricity for the PEFC, corresponding to fluctuation load of the next day. Accordingly, the reformed gas is used with a time shift operation. In this paper, the relation between operation method, power generation efficiency, and amount of heat storage of the SOFC–PEFC combined system to the difference in power load pattern was investigated. The average power generation efficiency of the system can be maintained at nearly 48% on a representative day in February (winter season) and August (summer season).

11/01397 Stochastic modeling and direct simulation of the diffusion media for polymer electrolyte fuel cells
Wang, Y. *et al. International Journal of Heat and Mass Transfer*, 2010, 53, (5–6), 1128–1138.
This paper combines the stochastic-model-based reconstruction of the gas diffusion layer (GDL) of polymer electrolyte fuel cells (PEFCs) and direct simulation to investigate the pore-level transport within GDLs. The carbon-paper-based GDL is modelled as a stack of thin sections with each section described by planar two-dimensional random line tessellations which are further dilated to three dimensions. The reconstruction is based on given GDL data provided by scanning electron microscopy (SEM) images. With the constructed GDL, the direct simulation of the coupled transport processes inside the GDL is introduced. The simulation considers the gas flow and species transport in the void space, electronic current conduction in the solid, and heat transfer in both phases. Results indicate a remarkable distinction in tortuosities of gas diffusion passage and solid matrix across the GDL with the former ~1.2 and the latter ~13.8. This difference arises from the synthetic microstructure of GDL, i.e. the lateral alignment nature of the thin carbon fibre, allowing the solid-phase transport to occur mostly in lateral direction. Extensive discussion on the tortuosity is also presented. The numerical tool can be applied to investigate the impact of the GDL microstructure on pore-level transport and scrutinize the macroscopic approach vastly adopted in current fuel cell modelling.

11/01398 Utilization of multiple graphene layers in fuel cells. 1. An improved technique for the exfoliation of graphene-based nanosheets from graphite
Saner, B. *et al. Fuel*, 2010, 89, (8), 1903–1910.
An improved, safer and mild method was proposed for the exfoliation of graphene like sheets from graphite to be used in fuel cells. The major aim in the proposed method is to reduce the number of layers in the graphite material and to produce large quantities of graphene bundles to be used as catalyst support in polymer electrolyte membrane fuel cells. Graphite oxide was prepared using potassium dichromate/sulfuric acid as oxidant and acetic anhydride as intercalating agent. The oxidation process seemed to create expanded and leafy structures of graphite oxide layers. Heat treatment of samples led to the thermal decomposition of acetic anhydride into carbon dioxide and water vapour which further swelled the layered graphitic structure. Sonication of graphite oxide samples created more separated structures. Morphology of the sonicated graphite oxide samples exhibited expanded the layer structures and formed some tulle-like translucent and crumpled graphite oxide sheets. The mild procedure applied was capable of reducing the average number of graphene sheets from 86 in the raw graphite to nine in graphene-based nanosheets. Raman spectroscopy analysis showed the significant reduction in size of the in-plane sp^2 domains of graphene nanosheets obtained after the reduction of graphite oxide.

15 ENVIRONMENT

Pollution, health protection, applications

11/01399 A system approach to the environmental analysis of industrial buildings
San-José Lombera, J.-T. and Garrucho Aprea, I. *Building and Environment*, 2010, 45, (3), 673–683.
The construction sector plays a major role in the development of society. It wields enormous influence over economic activity, employment and growth rates. However, it also has a substantial impact on the natural environment, the effects of which are evident across the world. Over recent decades, pioneering initiatives have proposed environmentally friendly buildings and sustainable construction has centred on residential and office buildings. Nevertheless, further consideration still needs to be given to sustainability in many areas of industrial construction. Accordingly, an integrated value model for sustainable assessment (MIVES) is presented that applies a set of six study scopes to define the sustainability criteria of industrial buildings. The system uses a requirements tree to quantify sustainability at various hierarchical levels, in order to assess the behaviour of industrial buildings and compliance with the criteria. Assignment of value functions to the sustainability criteria is then described in the context of a case study of a printing works, which demonstrates the effectiveness of this model at unifying both qualitative and quantitative indicators, in order to arrive at a specific 'environmental sustainability index' for the industrial building.

11/01400 Can environmental sustainability be used to manage energy price risk?
Henriques, I. and Sadorsky, P. *Energy Economics*, 2010, 32, (5), 1131–1138.
Energy security issues and climate change are two of the most pressing problems facing society and both of these problems are likely to increase energy price variability in the coming years. This paper develops and estimates a model of a company's energy price exposure and presents evidence showing that increases in a company's environmental sustainability lowers its energy price exposure. This result is robust across two different measures of energy prices. These results should be useful to companies seeking new ways of addressing energy price risk as well as governments concerned about the impact that energy price risk can have on economic growth and prosperity.

11/01401 Channelled optical fibre photoreactor for improved air quality control
Denny, F. *et al. Chemical Engineering Science*, 2010, 65, (2), 882–889.
An optical fibre reactor with 30 hexagonal-shaped channels distributed within the optical fibre structure was investigated as a gas-phase photocatalytic reactor. TiO_2 photocatalyst, with SiO_2 sol acting as a binder, was coated on the channel walls at a thickness of 1.5 μm. Effective light propagation lengths of 3.4 and 4.9 cm were observed for incidental angles of 81.5° and 87.1°, respectively. The TiO_2-coated channelled optical fibre reactor (COFR) was assessed for the photocatalytic degradation of gas-phase ethylene. The photocatalytic reaction rate of ethylene degradation was linear with respect to the incident photons. The reaction rate order for the incident photons was determined to be 0.93. Despite a longer effective light propagation length for an incidental angle of 87.1°, the quantum yield was independent of the incidental angle. The independence of the quantum yield on the incident photons and the angle of light incidence was attributed to the COFR design, where the propagating light was wholly confined within the reactor and, in turn, more effectively utilized by the TiO_2.

11/01402 City carbon budgets: a proposal to align incentives for climate-friendly communities
Salon, D. *et al. Energy Policy*, 2010, 38, (4), 2032–2041.

Local governments can have a large effect on carbon emissions through land use zoning, building codes, transport infrastructure investments, and support for transportation alternatives. This paper proposes a climate policy instrument – city carbon budgets – that provides a durable framework for local governments to reduce greenhouse gas emissions. Local governments would be assigned an emissions 'budget', and would be required to keep annual local transport and buildings emissions within this budget. This policy framework could be implemented and managed by a higher-level government, or might be used in awarding funds to developing country cities from international climate funds. The state of California has enacted a version of this policy. In this paper, the authors identify and evaluate options for creating an effective and acceptable institutional structure, allocating emission targets to localities, measuring emissions, providing flexibility and incentives to local governments, and assuring compliance. The likely costs of such a policy are also considered.

11/01403 Comfort monitoring? Environmental assessment follow-up under community–industry negotiated environmental agreements

Noble, B. and Birk, J. *Environment Impact Assessment Review*, 2011, 31, (1), 17–24.

Negotiated environmental agreements are becoming common practice in the mining industry. In principle, negotiated environmental agreements are said to respond to many of the shortcomings of environmental impact assessment by providing for improved follow-up of project impacts through, among other things, data provision, engaging stakeholders in the monitoring and management of project impacts, and building capacity at the local level to deal with project-induced environmental change. In practice, however, little is known about the efficacy of follow-up under negotiated environmental agreements between proponents and communities and the demonstrated value added to project impact management. This paper examines follow-up practice under negotiated environmental agreements with a view to understanding whether and how community-based monitoring under privatized agreements actually contributes to improved follow-up and impact management. Based on lessons emerging from recent experiences with environmental agreements in Canada's uranium industry, it is shown that follow-up under negotiated agreements may be described as 'comfort monitoring'. While such monitoring does improve community–industry relations and enhance corporate image, it does little to support effects-based management. If follow-up under negotiated agreements is to be credible over the long term, there is a need to ensure that monitoring results are useful for, and integrated with, regulatory-based monitoring and project impact management practices.

11/01404 Costs, CO_2- and primary energy balances of forest-fuel recovery systems at different forest productivity

Eriksson, L. and Gustavsson, L. *Biomass and Bioenergy*, 2010, 34, (5), 610–619.

The cost, primary energy use, and net carbon emissions associated with removal and use of forest residues for energy, considering different recovery systems, terrain, forwarding distance and forest productivity are examined. The authors show the potential recovery of forest fuel for Sweden, its costs and net carbon emissions from primary energy use and avoided fossil carbon emissions. The potential annual net recovery of forest fuel is about 66 TWh, which would cost one billion $€_{2005}$ to recover and would reduce fossil emissions by 6.9 Mt carbon if coal were replaced. Of the forest fuel, 56% is situated in normal terrain with productivity of >30 t dry-matter ha^{-1} and of this, 65% has a forwarding distance of <400 m. In normal terrain with >30 t dry-matter ha^{-1} the cost increase for the recovery of forest fuel, excluding stumps, is around 4–6% and 8–11% for medium and longer forwarding distances, respectively. The stump and small roundwood systems are less cost-effective at lower forest fuel intensity per area. For systems where loose material is forwarded, less dry-matter per hectare increases costs by 6–7%, while a difficult terrain increases costs by 3–4%. Still, these systems are quite cost-effective. The cost of spreading ash is around $40\ €_{2005}\ ha^{-1}$, while primary energy use for spreading ash in areas where logging residues, stumps, and small roundwood are recovered is about 0.025% of the recovered bioenergy.

11/01405 Development of a GIS-based decision support system for urban air quality management in the city of Istanbul

Elbir, T. *et al. Atmospheric Environment*, 2010, 44, (4), 441–454.

A decision support system has been developed for urban air quality management in the metropolitan area of Istanbul. The system is based on CALMET/CALPUFF dispersion modeling system, digital maps, and related databases to estimate the emissions and spatial distribution of air pollutants with the help of a GIS software. The system estimates ambient air pollution levels at high temporal and spatial resolutions and enables mapping of emissions and air quality levels. Mapping and scenario results can be compared with air quality limits. Impact assessment of air pollution abatement measures can also be carried out.

11/01406 Energy crop cultivations of reed canary grass – an inferior breeding habitat for the skylark, a characteristic farmland bird species

Vepsäläinen, V. *Biomass and Bioenergy*, 2010, 34, (7), 993–998.

This paper presents the first comparison of the abundance of farmland birds in energy grass fields and in cereal-dominated conventionally cultivated fields (CCFs). The author demonstrates that in boreal farmland, skylark (*Alauda arvensis*) densities were significantly lower in reed canary grass (RCG) (*Phalaris arundinacea*) fields than in CCFs. During the early breeding season, RCG fields and CCFs are equally good habitats, but over the ensuing couple of weeks RCG rapidly grows too tall and dense for field-nesting species. Consequently, RCG is an inferior habitat for skylark for laying replacement clutches (after failure of first nesting) or for a second clutch after one successful nesting. The results imply that if RCG cultivation is to be expanded, the establishment of large monocultures should be avoided in farmland landscapes; otherwise the novel habitat may affect detrimentally the seriously depleted skylark population, and probably also other field-nesting bird species with similar breeding habitats.

11/01407 Forest treatment residues for thermal energy compared with disposal by onsite burning: emissions and energy return

Jones, G. *et al. Biomass and Bioenergy*, 2010, 34, (5), 737–746.

Mill residues from forest industries are the source for most of the current wood-based energy in the USA, approximately 2.1% of the nation's energy use in 2007. Forest residues from silvicultural treatments, which include limbs, tops, and small non-commercial trees removed for various forest management objectives, represent an additional source of woody biomass for energy. The authors spatially analysed collecting, grinding, and hauling forest residue biomass on a 515,900 ha area in western Montana, US, to compare the total emissions of burning forest residues in a boiler for thermal energy with the alternatives of onsite disposal by pile-burning and using either natural gas or #2 distillate oil to produce the equivalent amount of useable energy. When compared to the pile-burn/fossil fuel alternatives, carbon dioxide emissions from the bioenergy alternative were approximately 60%, methane emissions were approximately 3%, and particulate emissions less than 10 μm were 11% and 41%, respectively, for emission control and no-control boilers. Emissions from diesel consumption for collecting, grinding, and hauling biomass represented less than 5% of the total bioenergy emissions at an average haul distance of 136 km. Across the study area, an average 21 units of bioenergy were produced for each unit of diesel energy used to collect, grind, and haul biomass. Fossil fuel energy saved by the bioenergy alternative relative to the pile-burn/fossil fuel alternatives averaged 14.7–15.2 GJ t^{-1} of biomass.

11/01408 Generation of typical meteorological year for different climates of China

Jiang, Y. *Energy*, 2010, 35, (5), 1946–1953.

Accurate prediction of building energy performance requires precise information of the local climate. Typical weather year files like typical meteorological year (TMY) are commonly used in building simulation. They are also essential for numerical analysis of sustainable and renewable energy systems. The present paper presents the generation of typical meteorological year (TMY) for eight typical cities representing the major climate zones of China. The data set, which includes global solar radiation data and other meteorological parameters referring to dry bulb temperature, relative humidity, wind speed, has been analysed. The typical meteorological year is generated from the available meteorological data recorded during the period 1995–2004, using the Finkelstein–Schafer statistical method. The cumulative distribution function (CDF) for each year is compared with the CDF for the long-term composite of all the years in the period. Typical months for each of the 12 calendar months from the period of years are selected by choosing the one with the smallest deviation from the long-term CDF. The 12 typical months selected from the different years are used for the formulation of a TMY.

11/01409 Impact of climate change on commercial sector air conditioning energy consumption in subtropical Hong Kong

Lam, T. N. T. *et al. Applied Energy*, 2010, 87, (7), 2321–2327.

Past and future trend of electricity use for air conditioning in the entire commercial sector in subtropical climates using 1979–2008 measured meteorological data as well as predictions for 2009–2100 from a general circulation model (MIROC3.2-H) was investigated. Air conditioning consumption showed an increasing trend over the past 30 years from 1979 to 2008. Principal component analysis (PCA) of measured and predicted monthly mean dry-bulb temperature, wet-bulb temperature

and global solar radiation was conducted to determine a new climatic index Z for 1979–2008 and future 92 years (2009–2100) based on two emissions scenarios B1 and A1B (low and medium forcing). Through regression analysis, electricity use in air conditioning for the 92-year period was estimated. For low forcing, average consumption in 2009–2038, 2039–2068 and 2069–2100 would be, respectively, 5.7%, 12.8% and 18.4% more than the 1979–2008 average, with a mean 12.5% increase for the entire 92-year period. Medium forcing showed a similar increasing trend, but 1–4% more. Standard deviations of the monthly air conditioning consumption were found to be smaller suggesting possible reduction in seasonal variations in future years.

11/01410 Lay perceptions of carbon capture and storage technology

Oltra, C. *et al. International Journal of Greenhouse Gas Control*, 2010, 4, (4), 698–706.

The extent of social acceptance of carbon capture and storage (CCS) is likely to significantly influence the sustainable development of CO_2 storage projects. Acceptance of CCS by the key stakeholders (policy makers, the general public, the media and the local community), linked to specific projects, as well as how the technology is communicated about and perceived by the public, have become matters of interest for the social sciences. This article reports on an investigation of the public perception of CCS technology in Spain. Individuals' views on CCS are analysed through focus groups with lay citizens using 'stimulus materials'. As the analysis shows, lay views of CCS differ significantly from the views of decision-makers and experts. Public concerns and reactions to CCS technology and potential projects, as well as the degree of consensus on its acceptance or rejection are detailed. Implications for the future use of CCS are discussed.

11/01411 Leaching experiments on a Mn-rich slag from the recycling of alkaline batteries – solid phase characterization and geochemical modeling

Pareuil, P. *et al. Applied Geochemistry*, 2010, 25, (8), 1187–1197.

Square sections of a manganese (Mn)-rich slag from an alkaline battery recycling plant were submitted to 6-month batch leaching procedures. High-purity water (HPW), acidic (pH 4) and alkaline (pH 12) conditions were used in order to observe the behaviour of primary solid phases as well as the constituent elements (Mn, Mg, Al, Si, Ca). The experiments were coupled with both KINDIS(P) modelling and mineralogical study (SEM-EDS). Experimental results showed that the Mn-rich slag was sensitive to acidic conditions that induced the dissolution of primary phases. Moreover, pH 4 conditions did not result in the formation of newly formed solid products, leading to the greatest mobilization of metallic elements (especially Mn). Alkaline conditions favored the precipitation of secondary phases, especially rhodochrosite, calcite and Mg-saponite, inducing low mobilization of the contained elements. The KINDIS(P) modelling allowed the stability of primary phases and newly formed products to be predicted. Although the modelled results have to be considered with caution, they allow the assessment and understanding of future environmental behaviour of the solid material in given conditions. In this case, the reuse of Mn-rich slag in acidic conditions has to be avoided because of the acidic dissolution of the primary phases.

11/01412 Monitoring urban transport air pollution and energy demand in Rawalpindi and Islamabad using leap model

Shabbir, R. and Ahmad, S. S. *Energy*, 2010, 35, (5), 2323–2332.

A research associated with urban transportation was carried out in Rawalpindi and Islamabad to analyse the status of emission of air pollutants and energy demands. The study included a discussion of past trends and future scenarios in order to reduce the future emissions. A simple model of passenger transport has been developed using computer based software called Long-Range Energy Alternatives Planning System (LEAP). The LEAP model was used to estimate total energy demand and the vehicular emissions for the base year 2000 and extrapolated until 2030 for the future predictions. Transport database in Rawalpindi and Islamabad, together with fuel consumption values for the vehicle types and emission factors of NO_x, SO_2 and PM_{10} corresponding to the actual vehicle types, formed the basis of the transport demand, energy consumption and total emission calculations. Apart from base scenario, the model was run under three alternative scenarios to study the impact of different urban transport policy initiatives that would reduce energy demand and emissions in transport sector of Rawalpindi and Islamabad. The prime objective was to arrive at an optimal transport policy, which limits the future growth of fuel consumption as well as air pollution.

11/01413 On-road traffic emissions in a megacity

D'Angiola, A. *et al. Atmospheric Environment*, 2010, 44, (4), 483–493.

A new annual bottom–up emission inventory of criteria pollutants and greenhouse gases from on-road mobile sources was developed for 2006 for the metropolitan area of Buenos Aires, Argentina, within a four-year regional project aimed at providing tools for chemical weather forecast in South America. Under the scarcity of local emission factors, the authors collected data from measuring campaigns performed in Argentina, Brazil, Chile and Colombia and compiled a data set of regional emission factors representative of Latin American fleets and driving conditions. The estimated emissions were validated with respect to downscaled national estimates and the EDGAR global emission database. The results highlight the role of older technologies accounting in average for almost 80% of the emissions of all species. The area exhibits higher specific emissions than developed countries, with figures two times higher for criteria pollutants. The effect on emissions of replacing gasoline by compressed natural gas, occurring in Argentina since 1995 was analysed. The authors identified (i) a relationship between number of vehicles and a compound socio-economic indicator, and (ii) time-lags in vehicle technologies between developed and developing countries, which can be respectively applied for spatial disaggregation and the development of projections for other Latin American cities. The results may also be employed to complement global emission inventories and by local policy makers as an environmental management tool.

11/01414 Strategic environmental assessment implementation in China – five-year review and prospects

Wu, J. *et al. Environment Impact Assessment Review*, 2011, 31, (1), 77–84.

Through literature review and questionnaire survey, the purpose of this study is to understand current status and major fields of SEA implementation in China, and then to provide advice for future improvement of SEA system, according to objective evaluation of the effectiveness of SEA implementation. Major types and fields of SEA implementation were firstly studied to conclude that the attitude of decision-makers and competent authority of SEA implementation does generate direct impacts on SEA implementation. Current status of SEA implementation were then studied, in terms of timing, techniques and methodologies, public participation, information disclosure, alternative, and review organization, to conclude that SEA implementation in China is 'impact-based SEA' and the major problems of SEA implementation are resulted from deficient and defective management of SEA system, such as laws, regulations, and means of management. In order to have objective evaluation on the effectiveness of SEA implementation, to understand good practice of SEA implementation, and to provide advice for future improvement of SEA system, it is necessary to establish reasonable and feasible evaluation criteria for the effectiveness of SEA implementation, based on foreign experience and political, legislative, administrative and cultural characteristics of China. Various types and stages of SEA should be carefully considered to be included into the evaluation criteria for the effectiveness of SEA implementation.

11/01415 Water use impact of ethanol at a gasoline substitution ratio of 5% from cassava in Nigeria

Adeoti, O. *Biomass and Bioenergy*, 2010, 34, (7), 985–992.

The process of fuel ethanol production from cassava root is connected to a chain of impacts on the water resource of the country where the cassava plant is grown and the root processed into fuel ethanol. The paper assesses the impact of the domestic production of 5% ethanol (E5) needed under the Nigerian biofuel programme from cassava root on the water resource of Nigeria. Using the 2007 premium motor spirit (PMS) consumption as the baseline, Nigeria will require about 0.49 hm^3 of ethanol to blend 9.32 hm^3 of PMS to arrive at the 2007 consumption estimates. The impact of the domestic production of this ethanol requirement translates to about 6.0 km^3 of water; out of which about 48% is green and about 52% is blue. Addressing future impact typical of a developing economy like Nigeria, a three-scenario analysis was adopted to examine the impact of future growth in cassava-fuel ethanol requirement on the water resource of Nigeria, and also, the impact of improved water use on the future water footprint of E5. The projected water impact of cassava-ethanol production into the future ranges from 6.02 to 7.28 km^3, while improved water use could lower these values by about 0.04–2.35 km^3 for the same period, 2010 to 2020, under the projection assumptions made.

CO_2, NO_x, SO_2 and particulate emissions

11/01416 A reactor network model for predicting NO_x emissions in gas turbines

Fichet, V. *et al. Fuel*, 2010, 89, (9), 2202–2210.

The numerical prediction of NO_x emissions from gas turbines is addressed in this paper. Generated from computational fluid dynamics (CFD), a reactor network (RN) is defined to model the NO_x formation

with a detailed chemistry. An optimized procedure is proposed to split the reactive flow field into homogeneous zones considered as perfectly stirred reactors (PSR). Once connected together, they result in a chemical reactor network (CRN) that yields a detailed composition regarding species and temperature in the combustion chamber. Sensitivity studies are then performed to estimate the influence of air humidity and gas turbine load on NO_x predictions. The NO_x emissions predicted are in good agreement with the measured data in terms of levels and trends for the case studied (a gas turbine flame tube fed with natural gas and functioning at a pressure of 15 bar). Finally, the RN methodology has shown to be efficient estimating accurately NO_x emissions with a short response time (few minutes) and small CPU requirements.

11/01417 Cost-effective CO_2 emission reduction through heat, power and biofuel production from woody biomass: a spatially explicit comparison of conversion technologies

Schmidt, J. *et al. Applied Energy*, 2010, 87, (7), 2128–2141.

Bioenergy is regarded as cost-effective option to reduce CO_2 emissions from fossil fuel combustion. Among newly developed biomass conversion technologies are biomass integrated gas combined cycle plants (BIGCC) as well as ethanol and methanol production based on woody biomass feedstock. Furthermore, bioenergy systems with carbon capture and storage (BECS) may allow negative CO_2 emissions in the future. It is still not clear which woody biomass conversion technology reduces fossil CO_2 emissions at least costs. This article presents a spatial explicit optimization model that assesses new biomass conversion technologies for fuel, heat and power production and compares them with woody pellets for heat production in Austria. The spatial distributions of biomass supply and energy demand have significant impact on the total supply costs of alternative bioenergy systems and are therefore included in the modelling process. Many model parameters that describe new bioenergy technologies are uncertain, because some of the technologies are not commercially developed yet. Monte-Carlo simulations are used to analyse model parameter uncertainty. Model results show that heat production with pellets is to be preferred over BIGCC at low carbon prices while BECS is cost-effective to reduce CO_2 emissions at higher carbon prices. Fuel production – methanol as well as ethanol – reduces less CO_2 emissions and is therefore less cost-effective in reducing CO_2 emissions.

11/01418 CO_2 capture and separation technologies for end-of-pipe applications – a review

Olajire, A. A. *Energy*, 2010, 35, (6), 2610–2628.

Carbon capture from point source emissions has been recognized as one of several strategies necessary for mitigating unfettered release of greenhouse gases (GHGs) into the atmosphere. To keep GHGs at manageable levels, large decreases in CO_2 emissions through capturing and separation will be required. This article reviews the possible CO_2 capture and separation technologies for end-of-pipe applications. The three main CO_2 capture technologies discussed include post-combustion, pre-combustion and oxyfuel combustion techniques. Various separation techniques, such as chemical absorption, physical absorption, physical adsorption, cryogenics, membrane technology, membranes in conjunction with chemical absorption and chemical-looping combustion (CLC) are also thoroughly discussed. Future directions are suggested for application by oil and gas industry. Sequestration methods, such as geological, mineral carbonation techniques, and ocean dump are not covered in this review.

11/01419 CO_2 emissions, electricity consumption and output in ASEAN

Lean, H. H. and Smyth, R. *Applied Energy*, 2010, 87, (6), 1858–1864.

This study examines the causal relationship between carbon dioxide emissions, electricity consumption and economic growth within a panel vector error correction model for five ASEAN countries over the period 1980–2006. The long-run estimates indicate that there is a statistically significant positive association between electricity consumption and emissions and a non-linear relationship between emissions and real output, consistent with the environmental Kuznets curve. The long-run estimates, however, do not indicate the direction of causality between the variables. The results from the Granger causality tests suggest that in the long-run there is unidirectional Granger causality running from electricity consumption and emissions to economic growth. The results also point to unidirectional Granger causality running from emissions to electricity consumption in the short-run.growth

11/01420 Emissions from premixed charge compression ignition (PCCI) combustion and affect on emission control devices

Parks II, J. E. *et al. Catalysis Today*, 2010, 151, (3–4), 278–284.

A light-duty diesel engine has been operated in advanced combustion modes known generally as premixed charge compression ignition (PCCI). The emissions have been characterized for several load and speed combinations. Fewer NO_x and particulate matter (PM) emissions are produced by PCCI, but higher CO and hydrocarbon (HC) emissions result. In addition, the nature of the PM differs from conventional combustion; the PM is smaller and has a much higher soluble organic fraction (SOF) content (68% vs 30% for conventional combustion). Three catalyst technologies were studied to determine the affects of HECC on catalyst performance; the technologies were a lean NO_x trap (LNT), diesel oxidation catalyst (DOC), and diesel particulate filter (DPF). The LNT benefited greatly from the reduced NO_x emissions associated with PCCI. NO_x capacity requirements are reduced as well as overall tailpipe NO_x levels particularly at low load and temperature conditions where regeneration of the LNT is difficult. The DOC performance requirements for PCCI are more stringent due to the higher CO and HC emissions; however, the DOC was effective at controlling the higher CO and HC emissions at conditions above the light-off temperature. Below light-off, CO and HC emissions are problematic. The study of DPF technology focused on the fuel penalties associated with DPF regeneration or 'desoot' due to the different PM loading rates from PCCI vs conventional combustion. Less frequent desoot events were required from the lower PM from PCCI and, when used in conjunction with an LNT, the lower PM from less frequent LNT regeneration. The lower desoot frequency leads an approximately 3% fuel penalty for a mixture of PCCI and conventional loads vs approximately 4% for conventional only combustion.

11/01421 Fuel-NO_x emissions reduction during the combustion of LCV gas in an air staged Winnox-TUD combustor

Adouane, B. *et al. Applied Thermal Engineering*, 2010, 30, (8–9), 1034–1038.

NO_x emissions from fuel-bound nitrogen (FBN) form one of the biggest challenges related to the combustion of biomass derived low calorific value (LCV) gas. To decrease the conversion of FBN to NO, one can intervene at different locations of the system: Upstream of the combustor using for example wet scrubbing techniques, downstream of the combustor using selective catalytic reduction (SCR), or selective non catalytic reduction (SNCR), or within the combustion system itself by optimizing the combustion process and the design parameters. In this research work, the third approach was adopted, where a new combustor called 'Winnox-TUD' was developed and tested. Winnox-TUD is an air staged combustor. Ammonia was injected in the LCV gas to simulate the FBN. In this paper the effect of stoichiometry in the first stage in addition to the effect of methane and ammonia concentrations on the conversion rate of FBN to NO are presented. Results are presented for both LCV gas containing and not containing natural gas in order to define the effect of methane. A minimum in the conversion rate of ammonia to NO was found at an air number in the primary stage (λ) between 0.7 and 0.8.

11/01422 Impact of air staging along furnace height on NO_x emissions from pulverized coal combustion

Fan, W. *et al. Fuel Processing Technology*, 2010, 91, (6), 625–634.

Experiments were carried out on an electrically heated multi-path air inlet one-dimensional furnace to assess NO_x emission characteristics of an overall air-staged (also termed air staging along furnace height) combustion of bituminous coal. The impact of main parameters of overall air-staged combustion technology, including burnout air position, air stoichiometric ratio, levels of burnout air (the number of burnout air arranged at different heights of the furnace), and the ratios of the burnout air flow rates and pulverized coal fineness of industrial interest, on NO_x emission were simulated to study in the experimental furnace, as well as the impact of air staging on the carbon content of the fly ash produced. These results suggest that air-staged combustion affects a pronounced reduction in NO_x emissions from the combustion of bituminous coal. The more deeply the air is staged, the further the NO_x emission is reduced. Two-level air staging yields a greater reduction in NO_x emission than single-level air staging. For pulverized coal of differing fineness, the best ratio between the burnout air rates in the two-level staging ranges from 0.6 to 0.3. In middle air-staged degree combustion with $f_M = 0.75$, pulverized coal fineness, R_{90} (%), has a greater influence on NO_x emission, whereas R_{90} has little influence on NO_x emission for deep air-staged degree with $f_M = 0.61$. Air-staged combustion with proper burnout air position has little effect on the burnout. For overall air-staged combustion, proper burnout air position and air-staged rate should be considered together in order to achieve high combustion efficiency.

11/01423 Influence of swirl number and fuel equivalence ratio on NO emission in an experimental LPG-fired chamber

Mafra, M. R. *et al. Applied Thermal Engineering*, 2010, 30, (8–9), 928–934.

The well-known kinetic mechanism of nitrogen oxides formation by thermal fixation of atmospheric nitrogen suggests the control of these pollutants by modifying the equivalence ratio and/or the temperature in the combustion region. In this experimental investigation a burner

was specifically designed to take advantages of these chemical kinetic aspects. In particular, it was used to investigate the influence of swirl number and fuel equivalence ratio on nitric oxide concentration formed in a cylindrical combustion chamber. A set of 14 experimental runs was carried out to examine the influence of these factors, which were varied at seven and two levels ($7^1 \times 2^1$) in the range of 0.36–1.32 and between 0.61 and 0.84, respectively. Liquefied petroleum gas (LPG) was always fired in the experiments. Temperature, O_2 and NO concentration were monitored in 42 different radial and axial positions along the chamber at four different operating conditions in terms of NO formation. The effect of increasing the swirl number and reducing the fuel equivalence ratio was to reduce approximately 31% and 33% the nitric oxide emission, respectively.

11/01424 Input–output analysis of Irish construction sector greenhouse gas emissions

Acquaye, A. A. and Duffy, A. P. *Building and Environment*, 2010, 45, (3), 784–791.

Ireland is committed to limiting its greenhouse gas (GHG) emissions to 113% of 1990 levels over the period 2008–12 and to 84% of 2005 levels by 2020 under the Kyoto Agreement and the EU's 2020 target by 2020, respectively. National policies have targeted many industry sectors but have failed to tackle directly GHG emissions associated with the construction activity. This paper estimates energy and GHG emissions intensities of the Irish construction sector and subsectors and estimates its contribution to Irish national emissions. This information is used to identify and assess the impacts of policy measures which would result in a reduction in emissions from the sector in a cost-effective manner. Energy and emissions intensities are estimated using input–output analysis techniques applied to Irish construction sector. In 2005 the Irish construction sector was responsible for the emission of 13.81 mtCO_{2eq}, comprising 2.37 mt (17%) of direct on-site emissions, 5.69 mt (41%) upstream indirect domestic emissions and 5.75 mt (42%) upstream indirect emissions outside the state. Domestically arising direct and indirect emissions accounted for 3.44% and 8.26% of national emissions respectively. Approximately three-quarters of construction sector emissions were the result of activities relating to NACE 45.2 'civil and structural construction works, etc.'. Given the potential importance of the construction sector to national emissions, there is scope for the implementation of policies which specifically target it. Two such policies are proposed: direct emissions mitigation through a construction EcoDriving initiative; and the provision of information to allow the design and specification of low-emissions materials.

11/01425 Modelling of a combined NO_x storage and NH_3-SCR catalytic system for Diesel exhaust gas aftertreatment

Chatterjee, D. *et al. Catalysis Today*, 2010, 151, (3–4), 395–409.

A combined diesel exhaust gas after-treatment system is studied, consisting of the NO_x storage and reduction catalyst (NSRC, called also lean NO_x trap, LNT) and the catalyst for selective catalytic reduction of NO_x by NH_3 (NH_3-SCR). Most of the time the system is operated under prevailing fuel-lean conditions, enabling economical running of the engine. During this phase the NO_x emissions are being adsorbed in the NSRC. However, short fuel enrichments need to be applied periodically for the NSRC regeneration (reduction of the stored NO_x). Ammonia produced in the NSRC as a by-product of the NO_x reduction under controlled fuel-rich conditions is then adsorbed in the NH_3-SCR reactor located downstream. The adsorbed NH_3 is consequently utilized in selective NO_x reduction during the next fuel-lean period. The NSRC + SCR configuration thus eliminates the need for an external NH_3 source (e.g. periodically re-filled urea solution tank) that is necessary in the case of the stand-alone SCR. Development of effective mathematical models for the NSRC and SCR catalysts is discussed. Dynamic measurements in a lab mini-reactor are performed separately for the industrial NSRC (PtRh/Ba/Ce/γ-Al_2O_3 type) and SCR (Fe-ZSM type) catalyst samples. The experimental results are employed in the evaluation of rate parameters for the individual catalysts. Particular attention is given to the dynamic evolution of NH_3 during the NSRC regeneration and its dependence on temperature and length of the enrichment period. Trends in NH_3 selectivity with the NSRC ageing are discussed. Synergistic effects of the NSRC and NH_3-SCR are then studied by simulations of defined lean/rich operation and engine test driving cycles. The combined NSRC + SCR system provides higher NO_x conversions in comparison with the stand-alone NSRC and it prevents undesired NH_3 slip. The positive effects of the downstream SCR are most important at lower intermediate temperatures, and in the case of an aged NSRC that usually produces more NH_3.

11/01426 NO_x removal over a double-bed NSR-SCR reactor configuration

Bonzi, R. *et al. Catalysis Today*, 2010, 151, (3–4), 376–385.

An analysis of the catalytic behaviour in the storage/reduction of NO_x of single Pt–Ba/Al_2O_3 LNT and FeZSM-5 SCR systems and of combined LNT + SCR configurations was considered in this work under clean conditions (i.e. in the absence of CO_2 and H_2O in the feed stream). By working under dilute conditions (i.e. with low reductant concentrations) and with an inert purge between the lean and the rich phases, nearly ideal isothermal conditions could be attained and the chemical pathways operating in the each step of the NSR cycle could be analysed for the investigated catalysts configurations. It is found that when the SCR catalyst is placed downstream the NSR catalyst bed (double-bed configuration), ammonia released from the LNT sample during the rich phase is stored on the SCR catalyst placed downstream and is then converted to N_2 in the subsequent lean phase according to the occurrence of a SCR reaction. This has a benefit on both the NO_x removal efficiency and the N_2 selectivity. If the zeolite SCR catalyst is mixed with the LNT sample (physical mixture), during the rich phase the SCR catalyst traps ammonia which being intermediate in N_2 formation leads to a decrease in the evolution of nitrogen at the reactor outlet. Ammonia stored on the SCR catalyst then reacts with NO_x during the subsequent lean phase, leading to a significant N_2 evolution: this increases the NO_x removal efficiency and the N_2 selectivity if compared to the single Pt–Ba/Al_2O_3 catalyst sample.

11/01427 On the way to 130 g CO_2/km – estimating the future characteristics of the average European passenger car

Fontaras, G. and Samaras, Z. *Energy Policy*, 2010, 38, (4), 1826–1833.

A new average CO_2 emissions limit for passenger cars was introduced in EU in 2009 imposing gradual average CO_2 emissions reduction to 130 g/km until 2015. This paper attempts to study possible changes in vehicle characteristics for meeting this limit taking into account the average European passenger car of 2007–2008. For this purpose first the most important factors affecting vehicle fuel consumption over the reference cycle (NEDC) are identified. At a second step, the CO_2 benefit from the optimization of these factors is quantified, through simulations of six different passenger cars commonly found in the European fleet. For the simulations Advisor 2002 was employed and validated against published type approval data. The analysis indicated that substantial reductions in vehicle weight, tyre rolling resistance and engine efficiency are necessary to reach even the 2008 target. A 10% reduction in average vehicle weight combined with 10% better aerodynamic characteristics, 20% reduced tyre rolling resistance and a 7.5% increase in average powertrain efficiency can lead to CO_2 reductions of approximately 13% (about 138 g/km based on 2007–2008 fleet-wide performance). Complying with the 130 g/km within the next 6-year timeframe will be a rather difficult task and additional technical measures appear to be necessary.

11/01428 Prediction of greenhouse gas reduction potential in Japanese residential sector by residential energy end-use model

Shimoda, Y. *et al. Applied Energy*, 2010, 87, (6), 1944–1952.

A model is developed that simulates nationwide energy consumption of the residential sector by considering the diversity of household and building types. Since this model can simulate the energy consumption for each household and building category by dynamic energy use based on the schedule of the occupants' activities and a heating and cooling load calculation model, various kinds of energy-saving policies can be evaluated with considerable accuracy. In addition, the average energy efficiency of major electric appliances used in the residential sector and the percentages of housing insulation levels of existing houses is predicted by the 'stock transition model'. In this paper, energy consumption and CO_2 emissions in the Japanese residential sector until 2025 are predicted. For example, as a business-as-usual case, CO_2 emissions will be reduced by 7% from the 1990 level. Also evaluated are mitigation measures such as the energy efficiency standard for home electric appliances, thermal insulation code, reduction of standby power, high-efficiency water heaters, energy-efficient behaviour of occupants, and dissemination of photovoltaic panels.

11/01429 Reduction of CO_2 emission and oil dependency with biomass-based polygeneration

Joelsson, J. M. and Gustavsson, L. *Biomass and Bioenergy*, 2010, 34, (7), 967–984.

This study compares different options for the use of lignocellulosic biomass to reduce CO_2 emission and oil use, focusing on polygeneration of biomass-based motor fuels and electricity, and discuss methodological issues related to such comparisons. The use of biomass can significantly reduce CO_2 emission and oil use, but there is a trade-off between the reductions in CO_2 emission and oil use. Bioelectricity from stand-alone plants replacing coal-based electricity reduced CO_2 emission by 99 kg per GJ biomass input but gave no oil use reduction. Stand-alone produced methanol replacing diesel reduced the CO_2 emission with 38 kg and the oil use with 0.67 GJ per GJ biomass, indicating that a potential CO_2 emission reduction of 90 kg is lost per

GJ oil reduced. CO_2 emission and oil use reduction for alternatives co-producing fuel and electricity fall between the stand-alone alternatives. Plug-in hybrid-electric vehicles using bioelectricity reduced CO_2 emission by 75–88 kg and oil use by 0.99–1.2 GJ, per GJ biomass input. Biomass can also reduce CO_2 emission and/or oil use more efficiently if fossil-fuel-fired boilers or electric heating is replaced by district heating from biomass-based combined heat and power generation. This is also true if electricity or motor fuel is produced from black liquor gasification in pulp mills or if wood is used instead of concrete in building construction. Biomass gasification is an important technology to achieve large reductions, irrespective of whether CO_2 emission or oil use reduction is prioritized.

11/01430 Simulation on catalytic reaction in diesel particulate filter

Yamamoto, K. *et al. Catalysis Today*, 2010, 153, (3–4), 118–124.
To reduce particulate matters (PM) in diesel exhaust gas, stricter exhaust emission standards such as Euro V are being set in many countries. Recently, for the after-treatment of exhaust gas, a diesel particulate filter (DPF) has been developed. Latest researches have shown that DPF filtration efficiency can be as high as 99%. However, the filter would be plugged with particles to cause an increase of filter back-pressure, which must be kept at lower levels, because the higher back-pressure increases fuel consumption and reduces available torque. This paper considers a NO_x-soot conversion system. There are two stages for PM oxidation. At the first step, the catalyst oxidizes NO in exhaust gas into NO_2. At the next step, NO_2 reacts with soot to produce CO and CO_2. However, the reaction rate and quantitative effect of NO_2 on soot oxidation is not clear, because it is difficult to observe small-scale phenomena in DPF experimentally, and there is not enough information on the PM oxidation. In this study, the above two-stage system was simulated. In the first part, the reaction with Pt catalyst for the oxidation of NO to NO_2 was simulated in non-porous flow-through filter. The catalytic reaction mechanism was discussed. In the second part, the flow in wall-flow filter was simulated to confirm the effectiveness of regeneration process by NO_2 in the real cordierite DPF.

11/01431 Towards real energy economics: energy policy driven by life-cycle carbon emission

Kenny, R. *et al. Energy Policy*, 2010, 38, (4), 1969–1978.
Alternative energy technologies (AETs) have emerged as a solution to the challenge of simultaneously meeting rising electricity demand while reducing carbon emissions. However, as all AETs are responsible for some greenhouse gas (GHG) emissions during their construction, carbon emission 'Ponzi schemes' are currently possible, wherein an AET industry expands so quickly that the GHG emissions prevented by a given technology are negated to fabricate the next wave of AET deployment. In an era where there are physical constraints to the GHG emissions the climate can sustain in the short term this may be unacceptable. To provide quantitative solutions to this problem, this paper introduces the concept of dynamic carbon life-cycle analyses, which generate carbon-neutral growth rates. These conceptual tools become increasingly important as the world transitions to a low-carbon economy by reducing fossil fuel combustion. In choosing this method of evaluation it was possible to focus uniquely on reducing carbon emissions to the recommended levels by outlining the most carbon-effective approach to climate change mitigation. The results of using dynamic life-cycle analysis provide policy makers with standardized information that will drive the optimization of electricity generation for effective climate change mitigation.

11/01432 Uncertainty analysis of developed ANN and ANFIS models in prediction of carbon monoxide daily concentration

Noori, R. *et al. Atmospheric Environment*, 2010, 44, (4), 476–482.
This study aims to predict daily carbon monoxide (CO) concentration in the atmosphere of Tehran by means of developed artificial neural network (ANN) and adaptive neuro-fuzzy inference system (ANFIS) models. Forward selection (FS) and Gamma test (GT) methods are used for selecting input variables and developing hybrid models with ANN and ANFIS. From 12 input candidates, 7 and 9 variables are selected using FS and GT, respectively. Evaluation of developed hybrid models and its comparison with ANN and ANFIS models fed with all input variables shows that both FS and GT techniques reduce not only the output error, but also computational cost due to less inputs. FS–ANN and FS–ANFIS models are selected as the best models considering R^2, mean absolute error and also developed discrepancy ratio statistics. It is also shown that these two models are superior in predicting pollution episodes. Finally, uncertainty analysis based on Monte-Carlo simulation is carried out for FS–ANN and FS–ANFIS models which shows that FS–ANN model has less uncertainty; i.e. it is the best model which forecasts satisfactorily the trends in daily CO concentration levels.

Hydrocarbon emissions

11/01433 A study on the coagulation of polycyclic aromatic hydrocarbon clusters to determine their collision efficiency

Raj, A. *et al. Combustion and Flame*, 2010, 157, (3), 523–534.
This paper presents a theoretical study on the physical interaction between polycyclic aromatic hydrocarbons (PAHs) and their clusters of different sizes in laminar premixed flames. Two models are employed for this study: a detailed PAH growth model, referred to as the kinetic Monte Carlo – aromatic site (KMC-ARS) model and a multivariate PAH population balance model, referred to as the PAH–primary particle (PAH-PP) model. Both the models are solved by kinetic Monte Carlo methods. PAH mass spectra are generated using the PAH-PP model, and compared to the experimentally observed spectra for a laminar premixed ethylene flame. The position of the maxima of PAH dimers in the spectra and their concentrations are found to depend strongly on the collision efficiency of PAH coagulation. The variation in the collision efficiency with various flame and PAH parameters is studied to determine the factors on which it may depend. A correlation for the collision efficiency is proposed by comparing the computed and the observed spectra for an ethylene flame. With this correlation, a good agreement between the computed and the observed spectra for a number of laminar premixed ethylene flames is found.

11/01434 Characteristics of polycyclic aromatic hydrocarbons emissions of diesel engine fueled with biodiesel and diesel

He, C. *et al. Fuel*, 2010, 89, (8), 2040–2046.
With mutagenic and carcinogenic potential, polycyclic aromatic hydrocarbons (PAHs) from mobile source exhaust have contributed to a substantial share of air toxics. In order to characterize the PAHs emissions of diesel engine fuelled with diesel, biodiesel (B100) and its blend (B20), an experimental study has been carried out on a direct-injection turbocharged diesel engine. The particle-phase and gas-phase PAHs in engine exhaust were collected by fibreglass filters and 'PUF/XAD-2/PUF' cartridges, respectively, then the PAHs were determined by a gas chromatograph/mass spectrometer (GC/MS). The experimental results indicated that comparing with diesel, using B100 and B20 can greatly reduce the total PAHs emissions of diesel engine by 19.4% and 13.1%, respectively. The benzo[*a*]pyrene (BaP) equivalent of PAHs emissions were also decreased by 15.0% with the use of B100. For the three fuels, the gas-phase PAHs emissions were higher than particle-phase PAHs emissions and the most abundant PAH compounds from engine exhaust were naphthalene and phenanthrene. The analysis showed that there was a close correlation between total PAHs emissions and particulate matter (PM) emissions for three fuels. Furthermore, the correlation became more significant when using biodiesel.

11/01435 Significance of polycyclic aromatic hydrocarbons (PAHs) in Permian/Triassic boundary sections

Nabbefeld, B. *et al. Applied Geochemistry*, 2010, 25, (9), 1374–1382.
In this study the abundances of several polycyclic aromatic hydrocarbons have been measured throughout three Permian/Triassic (P/Tr) sections from Meishan (South China), Kap Stosch area (East Greenland) and Peace River Basin (Western Canada). Dibenzothiophene and dibenzofuran were found to decrease in abundance just before or shortly after the P/Tr transition in all three sections while perylene was observed to increase in abundance at the onset of the main extinction horizon (bed 25) in Meishan. Perylene has been attributed to a wood degrading fungal source and, therefore, it seems possible these phenomena are related to the demise of land plants. Further, distinct patterns of various combustion-derived PAHs occurring in each section imply that forest fire events occurred within the Late Permian and Early Triassic. In the Meishan section high amounts of combustion-derived PAHs (pyrene, fluoranthene, benzo[*a*]anthracene, benzofluoranthenes, benzo[*a*]pyrene, benzo[*e*]pyrene and coronene) occur within bed 25, also containing ash attributed to the fallout from massive volcanic eruptions in Siberia and/or China.

Life cycle analysis

11/01436 An LCA-based environmental impact assessment model for construction processes

Li, X. *et al. Building and Environment*, 2010, 45, (3), 766–775.
A quantitative assessment of the environmental impact of construction activities can help decision-makers identify major environmental impact factors and make environmentally friendly construction plans in the early stages of construction. This paper presents an integrated

life cycle environmental impact assessment model that is applicable to construction phase studies, where impact factors are examined according to two aspects of a typical construction process: construction equipment and ancillary materials. Environmental impacts are categorized into three safeguard subjects: ecosystems, natural resources and human health. A disability adjusted life-year model for assessing human health damage due to construction dust is developed. In addition, the environmental impact of earthwork construction is assessed as a case study to demonstrate the application of the proposed model. Results indicate that the proposed model can effectively quantify the environmental impacts of construction processes, and can potentially be used as a tool for contractors to select environmentally friendly construction plans.

11/01437 Greenhouse gas impacts of ethanol from Iowa corn: life cycle assessment versus system wide approach

Feng, H. *et al*. *Biomass and Bioenergy*, 2010, 34, (6), 912–921.

Life cycle assessment (LCA) is the standard approach used to evaluate the greenhouse gas (GHG) benefits of biofuels. However, the need for the appropriate use of LCA in policy contexts is highlighted by recent findings that corn-based ethanol may actually increase GHG emissions. This is in contrary to most existing LCA results. LCA estimates can vary across studies due to heterogeneities in inputs and production technology. Whether marginal or average impacts are considered can matter as well. Most important of all, LCA is product-centred. The determination of the impact of biofuels expansion requires a system wide approach (SWA) that accounts for impacts on all affected products and processes. This paper presents both LCA and SWA for ethanol based on Iowa corn. LCA was conducted in several different ways. Growing corn in rotation with soybean generates 35% less GHG emissions than growing corn after corn. Based on average corn production, ethanol's GHG benefits were lower in 2007 than in 2006 because of an increase in continuous corn in 2007. When only additional corn was considered, ethanol emitted about 22% less GHGs than gasoline. SWA was applied to two simple cases. Using 2006 as a baseline and 2007 as a scenario, corn ethanol's benefits were about 20% of the emissions of gasoline. If geographical limits are expanded beyond Iowa, then corn ethanol could generate more GHG emissions than gasoline. These results highlight the importance of boundary definition for both LCA and SWA.

11/01438 Is life cycle assessment (LCA) a suitable method for quantitative CO_2 saving estimations? The impact of field input on the LCA results for a pure vegetable oil chain

Chiaramonti, D. and Recchia, L. *Biomass and Bioenergy*, 2010, 34, (5), 787–797.

The life cycle assessment (LCA) methodology is commonly agreed as the main tool for the estimation of the impact of biofuel chains, even in quantitative terms. This is also reflected in the recently issued EU directive (renewable energy directive, RED) on the promotion of the use of energy from renewable sources. However, the results of life cycle assessment works largely depend on the quality of the information given as input to the study, as also very recent research works started to investigate: in addition, the comparison of a large number of very different (technically, geographically, agronomically) biofuel chains, as some life cycle assessments and reviews tried to do, is a very difficult task due to the extremely large number of variable conditions and parameters. This paper, by considering a very specific biofuel chain (production and use of pure/straight sunflower oil in north-central Italy), discuss some limits and constraints of the application of the LCA method. The work investigated within which boundaries life cycle assessment could be implemented to perform quantitative assessments, as requested by the current supporting policies in the biofuel area. Results showed very large variations in the calculation of the CO_2 equivalent emissions, thus illustrating how achievable results depends on the local agricultural practices and performances, even for such a small and well-defined biofuel chain. The adoption of the present standardized life cycle assessment approach for generalized evaluations in the bioenergy sector and, in particular, for quantitative assessments should therefore be reconsidered. Concluding, LCA studies, even while addressing very specific and well defined chains, should always provide the bias of the calculations, as this range of variation of life cycle assessment results could be significantly greater than the initially set quantitative targets and therefore the whole investigation would be at risks of inconsistency. Proposals are finally given for small-scale projects, with the aim of developing sound but realistic processes to assess biofuel sustainability.

11/01439 LCA sensitivity analysis of a multi-megawatt wind turbine

Martínez, E. *et al*. *Applied Energy*, 2010, 87, (7), 2293–2303.

During recent years renewables have been acquiring gradually a significant importance in the world market (especially in the Spanish energetic market) and in society; this fact makes clear the need to increase and improve knowledge of these power sources. Starting from the results of a life cycle assessment (LCA) of a multi-megawatt wind turbine, this work is aimed to assess the relevance of different choices that have been made during its development. Looking always to cover the largest possible spectrum of options, four scenarios have been analysed, focused on four main phases of lifecycle: maintenance, manufacturing, dismantling, and recycling. These scenarios facilitate to assess the degree of uncertainty of the developed LCA due to choices made, excluding from the assessment the uncertainty due to the inaccuracy and the simplification of the environmental models used or spatial and temporal variability in different parameters. The work has been developed at all times using the of Eco-indicator99 LCA method.

11/01440 Life cycle assessment of geothermal binary power plants using enhanced low-temperature reservoirs

Frick, S. *et al*. *Energy*, 2010, 35, (5), 2281–2294.

Geothermal binary power plants that use low-temperature heat sources have gained increasing interest in the recent years due to political efforts to reduce greenhouse gas emissions and the consumption of finite energy resources. The construction of such plants requires large amounts of energy and material. Hence, the question arises if geothermal binary power plants are also environmentally promising from a cradle-to-grave point of view. In this context, a comprehensive life cycle analysis on geothermal power production from enhanced geothermal systems low-temperature reservoirs is performed. The results of the analysis show that the environmental impacts are very much influenced by the geological conditions that can be obtained at a specific site. At sites with (above) average geological conditions, geothermal binary power generation can significantly contribute to more sustainable power supply. At sites with less favourable conditions, only certain plant designs can make up for the energy and material input to lock up the geothermal reservoir by the provided energy. The main aspects of environmentally sound plants are enhancement of the reservoir productivity, reliable design of the deep wells and an efficient utilization of the geothermal fluid for net power and district heat production.

11/01441 Life-cycle energy and environmental analysis of bioethanol production from cassava in Thailand

Papong, S. and Malakul, D. *Bioresource Technology*, 2010, 101, (S1), S112–S118.

In this study, the life-cycle energy and environmental assessment was conducted for bioethanol production from cassava in Thailand. The scope covered all stages in the life cycle of bioethanol production including cultivating, chip processing, transportation and bioethanol conversion. The input–output data were collected at plantation sites and ethanol plants which included materials usage, energy consumption, and all emissions. From the energy analysis, the results show that cassava-based bioethanol has a negative net energy value with an energy ratio was less than 1, indicating a net energy loss. For the environmental performance, the results show that throughout the life cycle of bioethanol, the conversion stage contributes most to the environmental impacts which is due to the use of coal for power and steam production in the bioethanol plants. It is suggested that a partial substitution of coal with biogas produced from existing wastewater treatment could lead to a significant reduction in the environmental impact.

11/01442 The changing role of life cycle phases, subsystems and materials in the LCA of low energy buildings

Blengini, G. A. and Di Carlo, T. *Energy and Buildings*, 2010, 42, (6), 869–880.

A detailed life cycle assessment (LCA) has been conducted on a low energy family house recently built in northern Italy. The yearly net winter heat requirement is 10 kWh/m^2, while the same unit with legal standard insulation would require 110 kWh/m^2. As the building was claimed to be sustainable on the basis of its outstanding energy saving performances, an *ex post* LCA was set up to understand whether, and to what extent, the positive judgement could be confirmed in a life cycle perspective. The dramatic contribution of materials-related impacts emerged. The shell-embedded materials represented the highest relative contribution, but maintenance operations also played a major role. The contributions of plants, building process and transportation were minor. The important role of the recycling potential also emerged. Unlike standard buildings, where heating-related impacts overshadow the rest of the life cycle, there is no single dominating item or aspect. Rather, several of them play equally important roles. The study has confirmed that the initial goal of environmental sustainability was reached, but to a much lower extent than previously thought. In comparison to a standard house, while the winter heat requirement was reduced by a ratio of 10:1, the life cycle energy was only reduced by 2.1:1 and the carbon footprint by 2.2:1.

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Supplies, policy, economics, forecasts

11/01443 Asymmetric price responses and the underlying energy demand trend: are they substitutes or complements? Evidence from modelling OECD aggregate energy demand
Adeyemi, O. I. *et al. Energy Economics*, 2010, 32, (5), 1157–1164.
A number of energy demand studies have considered the importance of modelling asymmetric price responses (APR). This paper attempts to bring several strands of the literature together by proposing a testing procedure for the underlying energy demand trend (UEDT) and APR in energy demand models within both a panel context and the structural time series modelling framework. A set of tests across a range of specifications using time-series and panel data are therefore suggested in order to try and ascertain whether energy saving technical change (or the more general UEDT) and APR are substitutes for each other when modelling energy demand or whether they are actually picking up different influences and are therefore complements. Using annual whole economy data for 17 OECD countries over the period 1960–2006 the results suggest that for most of the countries the UEDT is preferred to APR, whereas for another group the UEDT and APR are complements, and for another group they are substitutes. It is argued therefore that energy demand modellers should not assume at the outset that one method is superior to the other. Moreover, wherever possible, a general model (be it in a time series or panel context) that includes a 'non-linear UEDT' and APR should be initially estimated, and only if accepted by the data should symmetry and/or a more restrictive UEDT be imposed.

11/01444 Building signatures: a holistic approach to the evaluation of heating and cooling concepts
Kalz, D. E. *et al. Building and Environment*, 2010, 45, (3), 632–646.
A sustainable and environmentally responsible building concept aims at a high workplace comfort, a significantly reduced heating and cooling demand, a high-efficient plant system, and the use of renewable energy sources to condition the built environment. This paper presents a comprehensive analysis of the heating and cooling concepts of 11 low-energy buildings in terms of energy use, efficiency and occupant thermal comfort. All buildings investigated employ environmental energy sources and sinks – such as the ground, groundwater, rainwater and the ambient air – in combination with thermoactive building systems. A limited primary energy use of about $100\,kWh_{prim}/(m^2_{net}a)$ as a target for the complete building service technology (HVAC and lighting) was postulated for all buildings presented. With respect to this premise, a comprehensive long-term monitoring in high time resolution was carried out for 2–5 years, with an accompanying commissioning of the building's performance. Measurements include the useful heating and cooling energy use, auxiliary energy use for the hydraulic system, as well as end and primary energy use, occupant thermal comfort and local meteorological conditions. A new methodology is proposed for a holistic approach to the evaluation of heating and cooling concepts, which not only considers the occupants thermal comfort, but also the useful energy consumption and the efficiency of the generation, distribution and delivery of heating and cooling energy.

11/01445 Energy assessment of peri-urban horticulture and its uncertainty: case study for Bogota, Colombia
Bojacá, C. R. and Schrevens, E. *Energy*, 2010, 35, (5), 2109–2118.
Scarce information is available about the energy use pattern of horticultural commodities in general and more specifically for peri-urban horticulture. Peri-urban horticulture in the outskirts of Bogota is an important source of vegetables for Colombia's capital city. Based on detailed follow-ups and periodic field measurements an output–input energy balance was performed with the main objective to study the energy use efficiency of those systems. An uncertainty analysis on the input factors and on the energy equivalents was then applied. Over a measurement period of 18-month, the energy use for coriander, lettuce, radish and spinach was investigated, respectively 12.1, 18.8, 6.6 and $10.7\,GJ\,ha^{-1}$ were consumed in these cropping systems. Negative balances were observed for all species exception made for spinach where an output : input ratio of 1.16 was found. The two-way uncertainty analysis showed the highest uncertainty for N-based fertilization while no significant effect was observed for seeds in direct sowing crops. Sustainability of peri-urban horticulture around Bogota is compromised not only because of the city expansion but also due to its inefficient energy use. Technical improvements are required to ensure the environmental subsistence of this important sector for the metropolitan area of the city.

11/01446 Energy consumption at the state level: the unit root null hypothesis from Australia
Narayan, P. K *et al. Applied Energy*, 2010, 87, (6), 1953–1962.
This paper examines the unit root null hypothesis in energy consumption for Australian states and territory. Sectoral energy consumption is considered for Australia and its six states and one territory using time series data for the period 1973–2007. This is the first study that does this. Generally, except for some cases in South Australia, strong support was found that shocks to energy consumption have a temporary effect on energy consumption in Australia.

11/01447 From potential forecast to foresight of Turkey's renewable energy with Delphi approach
Celiktas, M. S. and Kocar, G. *Energy*, 2010, 35, (5), 1973–1980.
A Delphi survey is a series of questionnaires that allow experts or people with specific knowledge to develop ideas about potential future developments around an issue. The Delphi questionnaires were developed throughout the foresight process in relation to the responses given by participants in bibliometric and SWOT analysis conducted prior to the Delphi survey. In this paper, Turkey's renewable energy future is evaluated using the Delphi method. A two-round Delphi research study was undertaken to determine and measure the expectations of the sector representatives regarding the foresight of renewable energies. First and second round of Delphi study were carried out by using online surveys. About 382 participants responded in the first round of the Delphi questionnaire yielding a respond rate of 20.1%, whereas 325 participants responded at the second round yielding a respond rate of 84.9%. About 50% of Turkey's energy demand was foresighted to be met by renewable energies around 2030. The results showed that all types of renewable energies would not only provide economic and environmental benefits but also improve living standards.

11/01448 Improvement characteristics shown in holistic regeneration of Ballymun toward sustainable community
Lee, Y. *et al. Building and Environment*, 2010, 45, (2), 279–286.
Substantial numbers of urban and residential environments constructed in the twentieth century are experiencing degeneration. However, there have been limitations in grasping the holistic regeneration information as urban regeneration usually goes through a long-term and complicated procedure. Yet, urban and housing regeneration direction is required to be holistic in the twenty-first century. Any precedent case that had tried holistic regeneration needs to be checked thoroughly and results applied to future attempts as a reference and knowledge base. The purpose of this study was to delineate improvement characteristics that appeared during the course of holistic regeneration in Ballymun, Ireland. This research is an archival research in nature which also used content analysis technique since it deals with reports and newsletters as archival records that were accumulated on a regular basis throughout the whole process. The leading projects continued for over 10 years and improvements were scrutinized in the perspective of physical, social, economic, cultural and environmental dimensions of regeneration. The main results were, first, a series of improvement activities and projects to regenerate each of the five dimensions delineated for comprehensive understanding. Second, connected patterns for synergistic improvement were identified and patterns were described to show the detailed contents as examples. This study would provide communities that face holistic regeneration with insight, planning skills, creative and realistic ideas for implementation, thereby empowering planning capability towards holistic regeneration.

11/01449 Influence of regional development policies and clean technology adoption on future air pollution exposure
Hixson, M. *et al. Atmospheric Environment*, 2010, 44, (4), 552–562.
Future air pollution emissions in the year 2030 were estimated for the San Joaquin Valley (SJV) in central California using a combined system of land use, mobile, off-road, stationary, area, and biogenic emissions models. Four scenarios were developed that use different assumptions about the density of development and level of investment in transportation infrastructure to accommodate the expected doubling of the SJV population in the next 20 years. Scenario 1 reflects current land-use patterns and infrastructure while scenario 2 encouraged compact urban footprints including redevelopment of existing urban centres and investments in transit. Scenario 3 allowed sprawling development in the SJV with reduced population density in existing urban centres and construction of all planned freeways. Scenario 4 followed currently adopted land use and transportation plans for the SJV. The air quality resulting from these urban development scenarios was evaluated using meteorology from a winter stagnation event that occurred on 15 December 2000 to 7 January 2001. Predicted base-case PM2.5 mass concentrations within the region exceeded $35\,\mu g\,m^{-3}$ over the 22-day episode. Compact growth reduced the PM2.5 concentrations by $\sim 1\,\mu g\,m^{-3}$ relative to the base-case over most of the SJV with the exception of increases ($\sim 1\,\mu g\,m^{-3}$) in urban centres driven by increased

concentrations of elemental carbon (EC) and organic carbon (OC). Low-density development increased the PM2.5 concentrations by 1–4 $\mu g\,m^{-3}$ over most of the region, with decreases (0.5–2 $\mu g\,m^{-3}$) around urban areas. Population-weighted average PM2.5 concentrations were very similar for all development scenarios ranging between 16 and 17.4 $\mu g\,m^{-3}$. Exposure to primary PM components such as EC and OC increased 10–15% for high density development scenarios and decreased by 11–19% for low-density scenarios. Patterns for secondary PM components such as nitrate and ammonium ion were almost exactly reversed, with a 10% increase under low-density development and a 5% decrease under high density development. The increased human exposure to primary pollutants such as EC and OC could be predicted using a simplified analysis of population-weighted primary emissions. Regional planning agencies should develop thresholds of population-weighted primary emissions exposure to guide the development of growth plans. This metric will allow them to actively reduce the potential negative impacts of compact growth while preserving the benefits.

11/01450 Policy options towards an energy efficient residential building stock in the EU-27

Uihlein, A. and Eder, P. *Energy and Buildings*, 2010, 42, (6), 791–798.
The EU-27 residential building stock offers high potential for energy efficiency gains. The policies already in place or proposed to improve the energy efficiency and thus the environmental performance focus on new buildings and major renovations of existing buildings. However, there might be additional measures that could lead to further energy efficiency improvements. In particular, the installation of roofs or windows that show a high thermal efficiency outside major renovations offer a large improvement potential. In this study, the potential environmental and economic impacts of two types of such policy options were analysed: first, measures that require high energy efficiency standards when roofs or windows have to be replaced; and, second, measures that accelerate the replacement of building elements. The results suggest that the two policies offer the potential for substantial additional energy savings. In addition, the installation of energy efficient building elements comes at negative net cost. When the replacement of building elements is accelerated, however, the additional costs do not outweigh the energy cost savings.

11/01451 Short term decisions for long term problems – the effect of foresight on model based energy systems analysis

Keppo, I. and Strubegger, M. *Energy*, 2010, 35, (5), 2033–2042.
This paper presents the development and demonstration of a limited foresight energy system model. The presented model is implemented as an extension to a large, linear optimization model, MESSAGE. The motivation behind changing the model is to provide an alternative decision framework, where information for the full-time frame is not available immediately and sequential decision making under incomplete information is implied. While the traditional optimization framework provides the globally optimal decisions for the modelled problem, the framework presented here may offer a better description of the decision environment, under which decision makers must operate. The authors further modify the model to accommodate flexible dynamic constraints, which give an option to implement investments faster, albeit with a higher cost. Finally, the operation of the model is demonstrated using a moving window of foresight, with which decisions are taken for the next 30 years, but can be reconsidered later, when more information becomes available. The results demonstrate some of the pitfalls of short term planning, e.g. lagging investments during earlier periods lead to higher requirements later during the century. Furthermore, the energy system remains more reliant on fossil based energy carriers, leading to higher greenhouse gas emissions.

11/01452 The causal relationship between energy consumption and GDP in Albania, Bulgaria, Hungary and Romania: evidence from ARDL bound testing approach

Ozturk, I. and Acaravci, A. *Applied Energy*, 2010, 87, (6), 1938–1943.
The purpose of this study is to investigate the causal relationship between energy and economic growth in Albania, Bulgaria, Hungary and Romania from 1980 to 2006 by employing energy use per capita, electric power consumption per capita and real GDP per capita variables. To examine this linkage a two-step procedure from the Engle and Granger model is used. In first step, the long-run relationships between the variables is explored using recently developed autoregressive distributed lag (ARDL) bounds testing approach of cointegration. Secondly, a dynamic vector error correction (VEC) model is used to test causal relationships between variables. The bounds test yields evidence of a long-run relationship between energy use per capita and real GDP per capita and evidence of two-way (bidirectional) strong Granger causality between these variables only in Hungary. On the other hand, the ARDL bounds test results show that there is not a unique long-term or equilibrium relationship between energy consumption variables and real GDP per capita in Albania, Bulgaria and Romania. In other words, no cointegration exists between these variables in these three countries. The econometric analysis suggests that any causal relationships within dynamic error correction model for Albania, Bulgaria and Romania cannot be estimated.

11/01453 The U.S. biodiesel use mandate and biodiesel feedstock markets

Thompson, W. *et al. Biomass and Bioenergy*, 2010, 34, (6), 883–889.
Studies of individual biodiesel feedstocks or broad approaches that lump animal fats and vegetable oils into a single aggregate straddle the true case of imperfect but by no means inconsequential substitution among fats and oils by different users. US biofuel policy includes a biodiesel use mandate that rises to almost 4 hm^3 by 2012, calling for biomass feedstock analysis that recognizes the complex interdependence among potential feedstocks and competition for food and industrial uses. Biodiesel input markets were modelled to investigate the implications of the mandate for quantities and prices with and without a provision disallowing biodiesel made from soybean oil. Findings suggest a hierarchy of price effects that tends to be largest for cheaper fats and oils typically used for industrial and feed purposes and smallest for fats and oils traditionally used exclusively for direct consumption, with the cross-commodity effects and other key economic parameters playing a critical part in determining the scale in each case. Although sensitive to the exact parameters used, the results argue against overly simplifying feedstock markets by holding prices constant when considering the economics of a particular feedstock or if estimating the broader impacts of rising biodiesel production on competing uses.

11/01454 Trends in world energy prices

Ghoshray, A. and Johnson, B. *Energy Economics*, 2010, 32, (5), 1147–1156.
The correct identification of the time series path of non-renewable energy resources has far reaching consequences for economists and policymakers alike. This study builds on the existing literature by employing a data series that includes a sample period of institutional change and recently developed unit root testing procedures. Besides crude oil, natural gas and coal prices are also examined, aiming to further the knowledge of non-renewable energy resource time paths in order to inform future research and update the conclusions of past studies. The unit root tests allow for structural breaks and are based on the procedures developed earlier works. Finally, the authors investigate whether the trend changes signs in the regimes which are bounded by the structural breaks and quantify the prevalence of the trends over the sample period considered. The results show that the trend is not well represented by a single positive or negative trend. The variability of the trend suggests that forecasting energy prices should not typically occur about a single trend.

11/01455 What goes up: recent trends in Mexican residential energy use

Rosas-Flores, J. A. and Gálvez, D. M. *Energy*, 2010, 35, (6), 2596–2602.
Energy use in the Mexican residential sector is steadily increasing. Important factors contributing to the increase include changes in the types of housing built, heating, cooling, water-heating equipment and other appliances. In this paper, the development of household equipment in Mexico is described between 1984 and 2006. Trend in energy consumption by end use is reviewed over the same period. Methodology based on energy end-uses shows that cooking is the main end use while water heating and appliances are the end uses with the greatest rates of growth.

Energy conservation

11/01456 Accounting frameworks for tracking energy efficiency trends

Ang, B. W. *et al. Energy Economics*, 2010, 32, (5), 1209–1219.
Many differences can be found among the existing accounting systems for tracking economy-wide energy efficiency trends. There is a need for greater uniformity in the design and application of such systems but a formal study does not exist. This paper seeks to fill some of the gaps. It begins by introducing the basic concepts, indicators and terminology in this study area. This is followed by a review of the existing economy-wide energy efficiency accounting systems with a focus on the analytical framework. The merit of having a precise and meaningful relationship between two basic energy indicators, the energy efficiency index and the energy savings due to efficiency improvement, is elaborated. An accounting framework based on the LMDI decomposition technique which possesses a number of desirable properties is proposed. Numerical examples are presented to highlight these properties and

show the differences among the various accounting frameworks. Several methodological and application issues are discussed, and the study concludes with key findings and recommendations.

11/01457 An energy-saving opportunity in producing lubricating oil using mixed-solventin simulated rotary disc contacting (RDC) extraction tower

Hatamipour, M. S. *et al. Energy*, 2010, 35, (5), 2130–2133.

Industrial processes are the most energy consuming processes in the world. Modification of these processes helps us with controlling the consumption of energy and minimizing energy loss. Changing raw materials is one of the ways through which industrial processes can be optimized. In this study, a new solvent mixture (furfural + a co-solvent) was used for the extraction of lubricating base oil from lube-oil cut. It was found that the energy consumption of the new solvent mixture for obtaining a product with the same quality was much lower than the original solvent. By using this new solvent mixture, the operating temperature of the top of tower was reduced by 30 K. This leads to a high reduction in energy consumption in extraction of aromatics from lube oil. At the new extraction process using new solvent mixture, the maximum energy saving was 38% per cubic meter of produced raffinate.

11/01458 An integrated empirical and modeling methodology for analyzing solar reflective roof technologies on commercial buildings

Jo, J. H. *et al. Building and Environment*, 2010, 45, (2), 453–460.

The energy savings and surface temperature reduction achieved by replacing an existing commercial building's flat roof with a more reflective 'cool roof' surface material is discussed. The research methodology gathered data on-site (surface temperatures and reflectivity) and used this in conjunction with the as-built drawings to construct a building energy simulation model. A 20-year cost-benefit analysis was conducted to determine the return on investment for the new cool roof construction based on the energy simulation results. The results of the EnergyPlus^{TM} simulation modelling revealed that reductions of 1.3–1.9% and 2.6–3.8% of the total monthly electricity consumption can be achieved from the 50% cool roof replacement already implemented and a future 100% roof replacement, respectively. This corresponds to a saving of approximately $22,000 per year in energy costs at current prices and a consequent 9-year payback period for the added cost of installing the 100% cool roof. The environmental benefits associated with these electricity savings, particularly the reductions in environmental damage and peak-time electricity demand, represent the indirect benefits of the cool roof system.

11/01459 Assessment of building façade performance in terms of daylighting and the associated energy consumption in architectural spaces: vertical and horizontal shading devices for southern exposure facades

Alzoubi, H. H. and Al-Zoubi, A. H. *Energy Conversion and Management*, 2010, 51, (8), 1592–1599.

This paper examines the effect of vertical and horizontal shading devices on the quality of daylight in buildings and the associated energy saving. Excessive daylight in architectural spaces contributes negatively to the energy consumption in buildings. Blinds and shading devices are good solutions to attenuate the surplus amount of daylight in spaces. Accordingly, this study evaluates the effect of shading devices on the amount of light flux and the associated solar energy in buildings. It estimates the energy consumption attributed to lighting spaces for three common positions of shading devices. Computer simulation strategy was undertaken to correlate the illuminance level in spaces with room geometry and architectural shading elements. The Holophane model for lighting calculations was used to estimate the average illuminance level on workplane and correlate it with the expected saving energy in buildings. The study concluded that there is an optimal orientation for shading devices that keeps the internal illuminance level within the acceptable range with minimum amount of solar heat gain.

11/01460 Can combining economizers with improved filtration save energy and protect equipment in data centers?

Shehabi, A. *et al. Building and Environment*, 2010, 45, (3), 718–726.

Economizer use in data centres is an energy efficiency strategy that could significantly limit electricity demand in this rapidly growing economic sector. Widespread economizer implementation, however, has been hindered by potential reliability concerns associated with exposing information technology equipment to particulate matter of outdoor origin. This study explores the feasibility of using economizers in data centres to save energy while controlling particle concentrations with high-quality air filtration. Physical and chemical properties of indoor and outdoor particles were analysed at an operating northern California data centre equipped with an economizer under varying levels of air filtration efficiency. Results show that when improved filtration is used in combination with an economizer, the indoor/outdoor concentration ratios for most measured particle types were similar to levels when using conventional filtration without economizers. An energy analysis of the data centre reveals that, even during the summer months, chiller savings from economizer use greatly outweigh any increase in fan power associated with improved filtration. These findings indicate that economizer use combined with improved filtration could reduce data centre energy demand while providing a level of protection from particles of outdoor origin similar to that observed with conventional design.

11/01461 Cooling strategies, summer comfort and energy performance of a rehabilitated passive standard office building

Eicker, U. *Applied Energy*, 2010, 87, (6), 2031–2039.

One of the first rehabilitated passive energy standard office buildings in Europe was extensively monitored over 2 years to analyse the cooling performance of a ground heat exchanger and mechanical night ventilation together with the summer comfort in the building. To increase the storage mass in the light-weight top floor, phase change materials (PCM) were used in the ceiling and wall construction. The earth heat exchanger installed at a low depth of 1.2 m has an excellent electrical cooling coefficient of performance of 18, but with an average cooling power of about 1.5 kW does not contribute significantly to cooling load removal. Mechanical night ventilation with two air changes also delivered cold at a good coefficient of performance of six with 14 kW maximum power. However, the night air exchange was too low to completely discharge the ceilings, so that the PCM was not effective in a warm period of several days. In the ground floor offices the heat removal through the floor to ground of 2–3 $W\,m^{-2}\,K^{-1}$ was in the same order of magnitude than the charging heat flux of the ceilings. The number of hours above 26 °C was about 10% of all office hours. The energy performance of the building was found to be excellent with a total primary energy consumption for heating and electricity of 107–115 $kW\,h\,m^{-2}\,a^{-1}$, without computing equipment only 40–45 $kW\,h\,m^{-2}\,a^{-1}$.

11/01462 Energy conservation in the greenhouse system: a steady state analysis

Singh, R. D. and Tiwari, G. N. *Energy*, 2010, 35, (6), 2367–2373.

This study evaluates the five typical shape of the greenhouse for energy conservation in winter months for a composite climate. An expression for the plant temperature has been used for steady state analysis. Numerical computation has been carried out for the climatic condition of Delhi, India. The evaluation of the shape of the greenhouse has been done for a given floor area. Additional energy required from other fuels to maintain the necessary temperature has also been considered. It has been observed that a standard peak uneven span is suitable for minimum use of liquefied petroleum gas for a given favourable plant temperature. Experimental validation of the thermal model has also been carried out.

11/01463 Energy consumption, prices and economic growth in three SSA countries: a comparative study

Odhiambo, N. M. *Energy Policy*, 2010, 38, (5), 2463–2469.

The causal relationship between energy consumption and economic growth in three sub-Saharan African countries, namely South Africa, Kenya and Congo (DRC) is considered. Prices are incorporated as an intermittent variable in a bivariate setting between energy consumption and economic growth – thereby creating a simple trivariate framework. Using the ARDL-bounds testing procedure, it is found that the causality between energy consumption and economic growth varies significantly across the countries under study. The results show that for South Africa and Kenya there is a unidirectional causal flow from energy consumption to economic growth. However, for Congo (DRC) it is economic growth that drives energy consumption. These findings have important policy implications insofar as energy conservation policies are concerned. In the case of Congo (DRC), for example, the implementation of energy conservation policies may not significantly affect economic growth because the country's economy is not entirely energy dependent. However, for South Africa and Kenya there is a need for more energy supply augmentations in order to cope with the long-run energy demand. In the short-run, however, the two countries should explore more efficient and cost-effective sources of energy in order to address the energy dependency problem.

11/01464 Energy efficiency assessment and improvement in energy intensive systems through thermoeconomic diagnosis of the operation

Usón, S. *et al. Applied Energy*, 2010, 87, (6), 1989–1995.

Advanced monitoring techniques can play a key role in improving energy efficiency of operating energy intensive systems. In particular, thermoeconomic diagnosis aims at the determination of fuel consumption variation, the identification of causes of its increment from design conditions and the quantification of the effect of each one of these causes. A thermoeconomic diagnosis system installed in a coal-fired

power plant has been used to analyse its operation during a time span of more than 6 years, quantifying the effects of variations in components (degradation, repairing and substitution), fuel quality, ambient conditions and operation strategy. The diagnosis method proposed (quantitative causality analysis) provides a precision of ±3% in addressing the source of inefficiency for about 70% of the cases.

11/01465 Energy efficient design and occupant well-being: case studies in the UK and India

Steemers, K. and Manchanda, S. *Building and Environment*, 2010, 45, (2), 270–278.

The aim of this paper was to demonstrate the relationships between sustainable building design and occupant well-being. It starts with a definition of sustainable design and well-being, and focuses on the relationships between energy performance and occupant feedback. Methodologically it draws on detailed monitoring and surveys of 12 case study office buildings in the UK and India, and the paper uses the data to explore whether energy use and associated CO_2 emissions are correlated to occupant satisfaction and comfort. The results demonstrate that increased energy use in the case study buildings is associated with increased mechanization (e.g. centralized air conditioning) and reduced occupant control. This reduced control in turn is shown to relate to reduced occupant comfort and satisfaction. Finally, the paper reveals that the reported health conditions of occupants correlates strongly with their levels of satisfaction. The overall conclusion is that energy use in typical office buildings is inversely correlated with the well-being of the occupants: more energy use does not improve well-being.

11/01466 Energy-saving judgment of electric-driven seawater source heat pump district heating system over boiler house district heating system

Shu, H. *et al. Energy and Buildings*, 2010, 42, (6), 889–895.

As a renewable energy utilization system, the electric-driven seawater source heat pump district heating system is gaining popularity in some coastal areas. However, under what conditions can the system achieve its energy-saving effect and how to evaluate its energy-saving potential are not clear in practice. In this paper, an expression of the critical *COP* value of the heat pump unit for energy-saving ($COP_{h,c}$) is derived through the comparison of the system and the conventional boiler house district heating system in the energy consumption respect. On the other hand, the actual *COP* values of the heat pump unit ($COP_{h,a}$) are calculated by an experimental data regression model on the basis of the manufacturer's dataset. The comparison of the values of $COP_{h,c}$ and $COP_{h,a}$ makes the energy-saving judgment of an electric-driven seawater source heat pump district heating system and its energy-saving potential, if it has, readily available. It was found that both the heating district radius and the natural conditions of the seawater are the most important factors that determine the energy efficiency of the system. And through comparison, it was also found that the type of the fuel of the boiler has significant impact on the crucial index value of $COP_{h,c}$.

11/01467 From net energy to zero energy buildings: defining life cycle zero energy buildings (LC-ZEB)

Hernandez, P. and Kenny, P. *Energy and Buildings*, 2010, 42, (6), 815–821.

There are various definitions of 'zero energy' and 'net-zero' energy building. In most cases, the definitions refer only to the energy that is used in the operation of the building, ignoring the aspects of energy use related to the construction and delivery of the building and its components. On the other hand the concept of 'net energy' as used in the field of ecological economics, which does take into account the energy used during the production process of a commodity, is widely applied in fields such as renewable energy assessment. In this paper the concept of 'net energy' is introduced and applied within the built environment, based on a methodology accounting for the embodied energy of building components together with energy use in operation. A definition of life cycle zero energy buildings (LC-ZEB) is proposed, as well as the use of the net energy ratio (NER) as a factor to aid in building design with a life cycle perspective.

11/01468 Is technological change biased toward energy? A multi-sectoral analysis for the French economy

Karanfil, F. and Yeddir-Tamsamani, Y. *Energy Policy*, 2010, 38, (4), 1842–1850.

Since the adoption and implementation of new technologies has an important influence on the structure and performance of the economy in both developed and developing countries, many research papers are devoted to the technology–economy nexus. Motivated by the fact that the impact of technical progress on the demand for different production factors may vary depending on the bias of the technological change, in this paper, by estimating a translog cost-share system and using state-space modelling technique, to what extent the direction of technical change is biased toward energy and away from other factors is investigated. By applying this methodology to the French economy for the period 1978–2006 the obtained results suggest that: first, technical change has a non-neutral impact on factor demands; second, capital-saving technical progress is present in the majority of the sectors studied; third, energy demand has increased in all sectors but electricity and gas. These findings may have important policy implications for environmental and energy issues in France.

11/01469 Modelling energy demand of developing countries: are the specific features adequately captured?

Bhattacharyya, S. C. and Timilsina, G. R. *Energy Policy*, 2010, 38, (4), 1979–1990.

This paper critically reviews existing energy demand forecasting methodologies highlighting the methodological diversities and developments over the past four decades in order to investigate whether the existing energy demand models are appropriate for capturing the specific features of developing countries. The study finds that two types of approaches, econometric and end-use accounting, are commonly used in the existing energy demand models. Although energy demand models have greatly evolved since the early seventies, key issues such as the poor–rich and urban–rural divides, traditional energy resources and differentiation between commercial and non-commercial energy commodities are often poorly reflected in these models. While the end-use energy accounting models with detailed sectoral representations produce more realistic projections as compared to the econometric models, they still suffer from huge data deficiencies especially in developing countries. Development and maintenance of more detailed energy databases, further development of models to better reflect developing country context and institutionalizing the modelling capacity in developing countries are the key requirements for energy demand modelling to deliver richer and more reliable input to policy formulation in developing countries.

11/01470 Neuro-optimal operation of a variable air volume HVAC&R system

Ning, M. and Zaheeruddin, M. *Applied Thermal Engineering*, 2010, 30, (5), 385–399.

Low operational efficiency especially under partial load conditions and poor control are some reasons for high energy consumption of heating, ventilation, air conditioning and refrigeration (HVAC&R) systems. To improve energy efficiency, HVAC&R systems should be efficiently operated to maintain a desired indoor environment under dynamic ambient and indoor conditions. This study proposes a neural network based optimal supervisory operation strategy to find the optimal set points for chilled water supply temperature, discharge air temperature and VAV system fan static pressure such that the indoor environment is maintained with the least chiller and fan energy consumption. To achieve this objective, a dynamic system model is developed first to simulate the system behaviour under different control schemes and operating conditions. A multi-layer feed forward neural network is constructed and trained in unsupervised mode to minimize the cost function which is comprised of overall energy cost and penalty cost when one or more constraints are violated. After training, the network is implemented as a supervisory controller to compute the optimal settings for the system. Simulation results show that compared to the conventional night reset operation scheme, the optimal operation scheme saves around 10% energy under full load condition and 19% energy under partial load conditions.consumption

11/01471 New developments in illumination, heating and cooling technologies for energy-efficient buildings

Han, H. J. *et al. Energy*, 2010, 35, (6), 2647–2653.

This paper gives a concise review of new designs and developments of illumination, heating and air-conditioning systems and technologies for energy-efficient buildings. Important breakthroughs in these areas include high-efficiency and/or reduced cost solar system components, LED lamps, smart windows, computer-controlled illumination systems, compact combined heat-power generation systems, and so on. To take advantage of these new technologies, hybrid or cascade energy systems have been proposed and/or investigated. A survey of innovative architectural and building envelope designs that have the potential to considerably reduce the illumination and heating and cooling costs for office buildings and residential houses is also included in the review. In addition, new designs and ideas that can be easily implemented to improve the energy efficiency and/or reduce greenhouse gas emissions and environmental impacts of new or existing buildings are proposed and discussed.

11/01472 Optimal energy planning models with carbon footprint constraints

Pękala, L. M. *et al. Applied Energy*, 2010, 87, (6), 1903–1910.

This paper describes a general modelling approach for optimal planning of energy systems subject to carbon and land footprint constraints. The methodology makes use of the source–sink framework derived from the analogies with resource conservation networks used in

process integration. Two variants of the modeling approach are developed for some of the important technologies for carbon emissions abatement: liquid biofuels in transportation, and carbon dioxide capture and storage in power generation. Despite the positive impact on environment, widespread use of these technologies has certain disadvantages. In case of biofuels, their production may strain agricultural resources, that are needed also for satisfying food demands. At the same time, carbon capture and storage is rather expensive technology and its practical implementation in power facilities must be carefully considered and planned. Optimum utilization of both technologies is identified with flexible and expandable mathematical modelling framework. Case studies are used to illustrate the variants of the methodology.

11/01473 Passive cooling for air-conditioning energy savings with new radiative low-cost coatings

Muselli, M. *Energy and Buildings*, 2010, 42, (6), 945–954.

Passive cooling is considered as an alternative technology to avoid unwanted heat gains, to reduce urban heat islands and to generate cooling potential for buildings (limiting air-conditioning energy). According to materials and surface treatments, the roof can represent to be a major heat gain source from opaque elements of the building fabric, heating up the outer surface and increasing heat flow by conduction. This paper presents low-cost new radiative materials (1 €/m^2) allowing to limit heat gains during diurnal cycle for hot seasons. To evaluate the relevance of these new substrates, their reflective UV–VIS–IR behaviour are studied and compared to classical roofed materials available in industrial and developing countries. A 48 m^2 experimental roof having different surfaces (plate steel sheets, fibre cement, terra cotta tiles and corrugated sheets) allows to determine the temperature ratio δ between uncoated and coated materials. Up to 34% surface temperature gains are obtained for white coated CS, 25% for FC and ~18% for TCT and PSS. According to uncoated materials for a surface temperature $T_0 = 60\,^{\circ}C$, simulations showed that the low-cost white opaque reflective roofs (50 m^2) presented in this study would reduce cooling energy consumption by 26–49%.

11/01474 Re-evaluating sustainability assessment: aligning the vision and the practice

Bond, A. J. and Morrison-Saunders, A. *Environment Impact Assessment Review*, 2011, 31, (1), 1–7.

Sustainable development is the core goal of the expanding field of sustainability assessment (SA). However, three key areas of debate in relation to SA practice in England and Western Australia can be classified as policy controversies. Through literature review and analysis of documentary evidence, the problem of reductionism (breaking down complex processes to simple terms or component parts) as opposed to holism (considering systems as wholes) is considered; the issue of contested understandings of the meaning of sustainability (and of the purpose of SA); and the definition of 'inter-generational' in the context of sustainable development and how this is reflected in the timescales considered in SA. The authors argue that SA practice is based on particular framings of the policy controversies and that the critical role of SA in facilitating deliberation over these controversies needs to be recognized if there is to be a move towards a new deliberative sustainability discourse which can accommodate these different framings.

11/01475 Saving energy by using underfloor-air-distribution (UFAD) system in commercial buildings

Alajmi, A. and El-Amer, W. *Energy Conversion and Management*, 2010, 51, (8), 1637–1642.

The number of attempts by researchers to reduce building energy consumption has increased, ever since global warming became a serious issue. In this trend, a relatively new approach of air distribution, underfloor-air-distribution system (UFAD), has been widely used in new commercial buildings. This technique is simply accomplished by supplying air through a raised floor using different types of distribution configurations and outlets. In UFAD, the air is directly supplied to the occupants' area (occupied zone) causing occupants plumes and zone heat load stratify to the upper layer of the zone (unoccupied zone), which are later extracted from return points at high level. This flow pattern gives UFAD the advantage of using less energy than a conventional air-distribution system, ceiling-based air distribution (CBAD) due to lower pressure drop and lower air flow rate. This paper investigates the effectiveness of UFAD systems in commercial buildings for various types of application and at different air supply temperatures in a hot climate (Kuwait). The findings show that UFAD has a significant saving of energy compared to CBAD (approximately 30%); in particular with high ceiling building types, as well as providing satisfactory comfort conditions for the occupants. Ultimately, more investigations should be done on conventional building heights (offices) to optimize the utilization of thermal stratification at design and operation stages.

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11/01476 An MILP model for optimization of byproduct gases in the integrated iron and steel plant

Kong, H. *et al. Applied Energy*, 2010, 87, (7), 2156–2163.

In iron and steel industry, byproduct gases are important energy. Therefore it is significant to optimize byproduct gas distribution to achieve total cost reduction. In this paper, a dynamic mixed integer linear programming (MILP) model for multi-period optimization of byproduct gases is used to optimize byproduct gas distribution. Compared with the previous optimization model, the proposed model simultaneously optimizes the distribution of byproduct gases in byproduct gas system, cogeneration system and iron- and steel-making system. Case study shows that the proposed model finds the optimal solution in terms of total cost reduction.

11/01477 Co-firing of refuse derived fuels with coals in cement kilns: combustion conditions for stable sintering

Haas, J. and Weber, R. *Journal of the Energy Institute*, 2010, 83, (4), 225–334.

The use of refuse-derived fuels (RDFs) in cement clinker processes has grown considerably in the past decade. It has been demonstrated that RDFs can partially substitute fossil fuels without compromising clinker quality. This paper considers RDF properties that are essential for stabilization of the sintering zone in the clinker burning process. An energy replacement indicator, defined as the RDF thermal input to the fossil fuel thermal input ratio, is used. Comminution of RDF to particle scales of pulverized fuel is not yet economically feasible and RDF is burnt at particle sizes in the order of several millimetres. Therefore, RDF combustion rates are orders of magnitudes smaller if compared to pulverized coal combustion rates. This shifts the flame zone downstream the rotary kiln and flame temperatures are reduced. A simple kiln combustion model has been used to examine the effects of RDF properties on sintering zone temperatures. RDFs with calorific values below 20 MJ kg^{-1} and coarse particle sizes burn at adiabatic temperatures below 2000°C. To compensate for this, the energy replacement ratio has to be increased to 114%. Calculations have shown several options to increase gas temperatures in sintering zones. The most effective would be the comminution of RDFs to pulverized fuel sizes. In this case, a further reduction of the RDF calorific value would be acceptable.

11/01478 Composition of high-calcium fly ash middlings selectively sampled from ash collection facility and prospect of their utilization as component of cementing materials

Sharonova, O. M. *et al. Fuel Processing Technology*, 2010, 91, (6), 573–581.

High-calcium fly ash middlings of brown coal of B2 (sub C) rank from the Berezovsky coal mine within the Kansk-Achinsk Basin were studied. The middlings were selectively sampled from the convection pass, the fore-hearth and each of the 4 fields of the electrostatic precipitator at the coal-fired power plant BSDPS-1. The differences of the dispersity, the chemical and mineral-phase composition and the cementing properties of these middlings, as well as the types in the ash classification system were determined. Within the ternary CaO-SiO_2-Al_2O_3 diagram, the equilibrium phases composition of the aluminosilicate constituent of middlings and the pozzolanic capacities of glasses of this system were analysed and compared with the actual phase composition. It was concluded that the fly ash middlings of the four fields of the electrostatic precipitator have the best prospect of utilization as component of cementing materials including portland cement and belite-sulfoaluminate cement.

11/01479 Landfill gas (LFG) processing via adsorption and alkanolamine absorption

Gaur, A. *et al. Fuel Processing Technology*, 2010, 91, (6), 636–640.

Landfill gas (LFG) was upgraded to pure methane using the adsorption and absorption processes. Different toxic compounds like aromatics and chlorinated compounds were removed using granular activated carbon. The activated carbon adsorbed toxic trace components in the following order: carbon tetrachloride > toluene > chloroform > xylene > ethylbenzene > benzene > trichloroethylene ≈ tetrachloroethylene. After removing all trace components, the gas was fed to absorption apparatus for the removal of carbon dioxide (CO_2). Two alkanolamines, monoethanol amine (MEA) and diethanol amine (DEA) were used for the removal of CO_2 from LFG. The maximum CO_2 loading is obtained for 30 wt% MEA which is around 2.9 mol L^{-1} of absorbent solution whereas for same concentration of DEA it is around 1.66 mol L^{-1} of solution. 30 wt% MEA displayed a higher absorption rate of around 6.64×10^{-5} mol L^{-1} min^{-1}. DEA displayed a higher

desorption rate and a better cyclic capacity as compared to MEA. Methane obtained from this process can be further used in the natural gas network for city.

11/01480 Mathematical modeling of heat recovery from a rotary kiln

Söğüt, Z. *et al. Applied Thermal Engineering*, 2010, 30, (8–9), 817–825.
In this study, heat recovery from rotary kiln was examined for a cement plant in Turkey. At first, an exergy analysis was carried out on the operational data of the plant. Results indicated the presence of 217.31 GJ of waste heat, which is 51% of the overall heat of the process. Then a mathematical model was developed for a new heat recovery exchanger for the plant. It was determined that 5% of the waste heat can be utilized with the heat recovery exchanger. The useful heat obtained is expected to partially satisfy the thermal loads of 678 dwellings in the vicinity through a new district heating system. This system is expected to decrease domestic-coal and natural gas consumption by 51.55% and 62.62% respectively. CO_2 emissions may also be reduced by 5901.94 kg/h and 1816.90 kg/h when waste heat is used instead of coal and natural gas.

11/01481 Performance analysis of a membrane-based energy recovery ventilator: effects of membrane spacing and thickness on the ventilator performance

Min, J. and Su, M. *Applied Thermal Engineering*, 2010, 30, (8–9), 991–997.
A mathematical model was built to predict the thermal–hydraulic performance of a membrane-based energy recovery ventilator. Calculations were conducted to investigate the effects of the membrane spacing (channel height) and membrane thickness on the ventilator performance under equal fan power conditions. The results show that for a fixed fan power, as the channel height increases, the total heat transfer rate initially increases, after reaching a maximum at a certain channel height, turns to decrease. A larger fan power leads to a larger total heat transfer rate, with the maximum total heat transfer rate occurring at a smaller channel height. As the channel height or the fan power increases, the enthalpy effectiveness decreases. Further, as the membrane thickness increases, both the total heat transfer rate and enthalpy effectiveness decrease.

11/01482 The waste-to-energy framework for integrated multi-waste utilization: waste cooking oil, waste lubricating oil, and waste plastics

Singhabhandhu, A. and Tezuka, T. *Energy*, 2010, 35, (6), 2544–2551.
Energy generation by wastes is considered one method of waste management that has the benefit of energy recovery. From the waste-to-energy point of view, waste cooking oil, waste lubricating oil, and waste plastics have been considered good candidates for feedstocks for energy conversion due to their high heating values. Compared to the independent management of these three wastes, the idea of co-processing them in integration is expected to gain more benefit. The economies of scale and the synergy of co-processing these wastes results in higher quality and higher yield of the end products. This study uses cost-benefit analysis to evaluate the integrated management scenario of collecting the three wastes and converting them to energy. The authors report the total heat of combustion of pyrolytic oil at the maximum and minimum conversion rates, and conduct a sensitivity analysis in which the parameters of an increase of the electricity cost for operating the process and increase of the feedstock transportation cost are tested. The effects of economy of scale were evaluated in the case of integrated waste management. Four cases of waste-to-energy conversion are compared with the business-as-usual scenario, and the results show that the integrated co-processing of waste cooking oil, waste lubricating oil, and waste plastics is the most profitable from the viewpoints of energy yield and economics.

11/01483 Thermal transformation of organic matter in coal waste from Rymer Cones (Upper Silesian Coal Basin, Poland)

Misz-Kennan, M. and Fabiańska, M. *International Journal of Coal Geology*, 2010, 81, (4), 343–358.
Coal wastes produced at various stages of coal mining, washing and deposition on dumps are a source of many pollutants. In some cases, the dumped coal waste undergoes self-heating and self-combustion processes that reflect the properties of the organic matter present (maceral composition and rank) and the history of heating (rate, time and temperature of heating). In the examination of the coal wastes from the Rymer Cones dump, petrographic- and gas chromatography-mass spectrometry (GC-MS) techniques were used to provide different sets of complementary data. Unaltered- and variably-altered macerals (mostly vitrinite) characterize the investigated material. Vitrinite of elevated reflectance and massive coke particles indicate that the rate of heating was low and that the availability of air was very limited; heating took place under pyrolytic conditions. Irregular cracks in particles probably also resulted from slow heating. The temperature of the heating processes, dynamically changing in time and place throughout the dump, led to chemical changes in organic matter such as the formation of phenols and their derivatives, and alteration in distributions of *n*-alkanes, hopanes and moretanes and polycylic aromatic hydrocarbons (PAHs) occurring in pyrolysates. Some of these compounds formed as a result of the thermal destruction of liptinite and vitrinite macerals at various temperatures and migrated from within the dump. The changes that occurred within the dump are also reflected in values of geochemical parameters based on the same compounds, such as CPI, Ts/(Ts + Tm), MNR, DNR, TNR-1, TNR-2. Lighter compounds were probably released into the atmosphere and others, especially phenols that are easily soluble in water and PAHs, were most probably leached into deeper parts of the dump and even into underground waters since they are absent in some samples or significantly decreased in concentration. These processes probably still continue – it is this fact that creates a potential hazard to the environment.

11/01484 Thermochemical recycling of mixture of scrap tyres and waste lubricating oil into high caloric value products

Abdul-Raouf, M. E. *et al. Energy Conversion and Management*, 2010, 51, (6), 1304–1310.
Scrap tyres and used lubricating oils represent together growing environmental problem because they are not biodegradable and their components cannot readily be recovered. In the present investigation, the thermochemical recycling of mixture of old tyres with waste lubricating oil by pyrolysis and the value of the products obtained have been studied. First, thermobalance experiments were carried out, studying the influence of the following variables: temperature, type of catalyst and catalyst concentration on the pyrolysis reaction of a mixture of 1/1 wt/wt oil/tyre ratio. These thermobalance results were thoroughly investigated to study the effect of the main process variables on yields of derived products: oils, gases and solid residue.