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NEWSLETTER

of the

Fuel & Energy Research Forum

EDITOR'S NOTES

Some of our regular readers may be somewhat surprised to find another issue of our erstwhile Coal Research Forum Newsletter, now the FERF Newsletter, dropping metaphorically speaking onto their doormat – there I go showing my age again! The reason for the change of issue dates is because, in keeping with our new remit, we have decided, well I have decided really, to issue four newsletters a year instead of three. They will be shorter in length and will hopefully contain newer information and articles on our broader interests. The dates for issue will be July, October, December and April so the first in this new format is the July 2017 edition.

The main feature in this newsletter is a detailed report on the presentations given as part of our annual meeting held at the University of Nottingham on April 26th.

The inaugural seminar of FERF's Biomass & waste interest Group took place on 27th June at the University of Leeds. This collaborative event between the FERF and the EPSRC Bioenergy CDT Group was entitled "Low grade biomass – Challenges and opportunities". The event attracted over 100 attendees and will be reported in the next newsletter which will be produced in October.

Also featured is the list of new EPSRC funded projects which started on 1st January 2017 in the fields of CCS, Bioenergy and Waste Management.

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Student bursaries for 2017-2018

Travel and subsistence bursaries of up to £300 are on offer to bona-fide full-time students who wish to attend appropriate National and International coal-related conferences, (please see the Calendar of Fuel and Energy Research Events for details of future conferences), and whose supervisor is a member of the Fuel and Energy Research Forum. To apply, please send the abstract submitted to the conference with a brief supporting letter from your supervisor together with details of the expected expenditure and other sources of funding applied for, to:

Professor J.W. Patrick,
Dept. of Chemical and Environmental Engineering,
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The requirements for eligibility for award of a bursary are that the recipient will submit a short report about his or her impressions of the conference to the Newsletter Editor for inclusion in the next edition. In addition, this report will provide some brief details of the beneficiary, their topic of study and the reasons for wishing to attend the conference. Potential applicants should see the template for these reports on the FERF website, http://www.tferf.org where such reports must comply with these requirements.

Please note that these bursaries are only for travel and subsistence to attend the conference, (i.e. not for conference or other fees). In addition, priority will be given to applicants who will be attending the whole of a conference rather than one day of a multi-day event and will be using the conference accommodation provided should this be required. It may not be possible to fund all applications for bursaries or meet the request in full as this will depend on the funds available at the time.

Report of 28th CRF/1st FERF Annual Meeting and Meeting of the Combustion Interest Group

26th April 2017

University of Nottingham

The 28th Annual Meeting of the Coal Research Forum was held in conjunction with the 1st Annual Meeting of the Fuel and Energy Research Forum and a meeting of the Combustion Interest Group in the Business School South Building of the University of Nottingham's Jubilee Campus. The meeting followed the usual format with the Annual Meeting being held at lunch time preceded and followed by a series of technical sessions. The theme for the technical sessions was "Combustion Safety and Flame Stability".

Session 1 was opened by chairman Gerry Riley of RJM International who echoed the views of a number of attendees by expressing the long-overdue need for such a seminar. Gerry's topic served as an introduction and was entitled "Fuel Safety – A Utility Perspective". He began in his own inimitable style by itemising the different ways in which a lack of safety could have very serious impacts. Failure to adhere to safe working practises could lead to human tragedy, financial ruin, a loss of reputation, morale or brand name. It could prevent the ability of a plant to operate and in certain cases lead to imprisonment.

Gerry highlighted potential safety problems in the storage of bulk coals, their milling and combustion and with ash and slag. Coals with a tendency to spontaneously ignite cause at best a loss of revenue to the operator and at worst can result in catastrophic failure, as shown by a videoclip of the collapse of a burning coal conveyor. This was the result of reclaiming hot coal from the stockpile. Coal milling can be hazardous as videos of dust explosions graphically showed. Similar damage from coals with poor flame stability can also result in serious damage to the boiler if the unburnt pulverised coal collects in the furnace then ignites. Certain coals tend to swell and soften and can cause blockage in the burner nozzles of low NOx burners. Not only will this cause severe damage to the burner nozzle but can result in fires which can spread to other parts of the combustion system. Ash and slag build-up in the furnace can cause problems during boiler outages as these large masses can become detached from heat transfer surfaces endangering personnel who may be inside the furnace.

Dust deposition in the transportation of pulverised fuels, in particular biomass, will result in an increased risk of explosion. Gerry ended his talk with the observation that in the UK it is probably true to say that without being a safe business you won’t have a business.

The second presentation was given by James Luxford of RWE Generation UK and was entitled “Dust Explosions and their Management (DSEAR)”. James began his talk by explaining the differences between a fire and an explosion. The dispersion of fuel particles in air resulting in an explosion will produce a higher rate of energy release than a fire. Explosions exert higher pressures, can cause rapid damage and may lead to subsequent explosive events. The consequences of explosions are usually more severe than those of a fire. James also gave an estimation of the frequency of explosions in the UK: gas/vapour explosions ~1 per day; dust explosions ~1 per month and mist explosions ~1 per year.

Explosions are combatted by reducing the risk associated with a process by using SFAIRP, (So far as is reasonably practical), following Health & Safety at Work and DSEAR (Dangerous Substances and Explosive Atmospheres Regulations) legislation. DSEAR legislation requires measures to be taken to ensure the safety of those who may be affected by the presence of dangerous substances in the workplace. This requires that risk assessment, risk reduction, hazardous area classification and ignition source control are performed and necessary measures are implemented. Accident/injuries and emergency plans must be in place. This is done by trying to understand the explosion mechanism, reviewing available risk reduction options, assessing risk and showing that further risk reduction measures are not practical.

James moved on to explain the similarities and differences between the two major causes of explosions, namely gas/vapour and dust. Aspects common to both types of explosions are the need for a minimum amount of material to sustain a reaction and the necessary heat or energy of material as are their responses to burning velocity and cloud turbulence. Where these two types of explosion differ is that gases generally have consistent properties whereas dusts vary greatly in their chemical composition, particle shape, size distribution, moisture content and their tendency to self-heat and agglomerate.

Flammable dusts are also more complex to analyse than gases and vapours. Modelling of dust explosion is extremely difficult and there is no clear maximum explosive concentration (UEL equivalent). Dusts are often a fraction of a bulk cargo such as wood or coal which in themselves are not explosible.

Liquid, gas and vapour explosions generally occur externally to the process equipment and are driven by the system pressure, i.e. leakage or venting. The ignition source is external to the system and is generally unrelated to the substance itself.

Dust explosions often occur within the process vessel, i.e. coal being milled and interactions between the substance and the equipment is a key issue. This can be made worse by the occurrence of tramp material and the tendency of the substance to self-heat or agglomerate.

Hazardous area classification is used to determine the required degree of ignition source control. Zones where potentially explosive atmospheres may form, the frequency with which they may form and their persistence when formed are all important factors for consideration. Areas where an explosive atmosphere is present continuously or for long periods is termed "Zone 20", where such an atmosphere is likely to occur in normal operations occasionally is "Zone 21" and where not likely to occur in normal operations but if it does occur will persist for only a short period is "Zone 22".

[*Teach in (for those who need it!) on explosion indices test (K_{st} value and P_{max})]*
K_{st} value and P_{max} are explosive properties measured in the laboratory to quantify the severity of a dust explosion. The explosion indices test follows BS EN 14034-1:2004 (determination of the maximum explosion pressure P_{max} of dust clouds) and BS EN 14034-2:2006 (determination of the maximum rate of explosion pressure rise of dust clouds K_{st}). The tests are carried out in a 20 litre sphere apparatus which reproduces a high state of turbulence to simulate worst case process plant conditions. A weighed quantity of combustible dust is placed into the dust container.

The main explosion chamber is then evacuated to 0.4 bar absolute. An automatic test sequence is initiated to pressurise the dust container to 20 bar gauge, and then the fast acting valve on the dust container outlet is opened to allow material into the explosion chamber. The rebound nozzle ensures an even distribution of dust within the explosion chamber and the control system activates two 5 KJ chemical igniters at the centre of the sphere 60ms after the dust has been dispersed. Explosion pressures are measured for a range of dust concentrations using piezo-electric pressure transducers.

The tests are carried out over three series to ensure a thorough investigation of the explosion properties. From the tests, the arithmetic mean of the maximum values (both maximum pressure and maximum rate of pressure rise) is obtained. The K_{st} value is calculated as the equivalent pressure in a 1 m^3 or 20 litre sphere from the cube law (K_{st} value = cube root of volume x explosion pressure rise).The ST class is based on the K_{st} value as follows: ST class 0 - K_{st} value = 0; ST class 1 - K_{st} value less than 200 bar m/sec; ST class 2 - K_{st} value between 200 and 300 bar m/sec; ST class 3 - K_{st} value greater than 300 bar m/sec. Explosion testing for K_{st} value & P_{max} is essential to validate protection design (explosion venting, explosion suppression and explosion containment). Results of testing are shown in the table below: -

Substance	*Pmax (barg)*	*Kst (bar ms^{-1}*	*ST class*
Wood pellet dust	*7 to 9*	*78 to 186*	*1*
Coal dust (semi-anthracite)	*7*	*95*	*1*
Coal dust (high volatile bituminous)	*8*	*135*	*1*
Aluminium powder	*11.5*	*408*	*3*

Data obtained from testing are not properties of the substance but the information can be used to gauge the risk from using a particular substance before it is received or used. Data can also provide information on suitable explosion prevention methods through the selection of equipment to prevent dust release and to control ignition and to assist in process decisions such as, for example, retention time in storage and operating temperatures.

Explosion protection can take several forms. This may involve preventing an explosive atmosphere from forming; containment of the pressure of any resulting explosion; explosion pressure relief, suppression or isolation. Explosion containment can be expensive and is used mainly on smaller vessels rather than large silos. It requires isolation from other areas of the process and the plant must be regularly checked to ensure that it will perform as designed. Explosion pressure relief or venting makes use of a deliberately weakened panel in the system which will rupture and relieve any pressure build up. A flame arrestor can be used which will protect personnel if there is an explosion in a plant which is indoors. Explosion suppression uses pressure detectors and cylinders of sodium bicarbonate. When triggered, a rapid discharge into the process vessel occurs to quench the developing explosive event. It is a very useful method where explosion venting cannot sensibly be used, i.e. in doors or where the release of toxic substances must be avoided.

If the intention is to use explosion isolation one needs to recognise that most solid, dust or powder handling systems are interconnected and may contain equipment such as grinders, mills, bag filters, cyclones and silos. It will be necessary to prevent propagation throughout the system to prevent widespread damage and harm to operators and to limit the consequences to any particular area. The approach often used is to divide the plant into areas and protect each area individually and to isolate each from the others.

Secondary dust explosions occur when a primary explosion raises a dust cloud from adjacent equipment which is then ignited by the heat from the primary explosion. The incidence of these thankfully rare but usually involve deaths and significant damage to plant. Primary explosions of gas and dust typically occur in process equipment and the quantity of material i.e. the layer thickness and spread dominates over other factors in determining consequences.

James concluded his wide-ranging talk with an assessment of the current status where clearly there is further work to be done to improve the overall safety of process plant. These concerns include understanding the actual conditions within process equipment, that is, how should one use data; from “real plant” or test rig geometry or CFD? Also of importance is the need for guidance on explosion protection given that large silos for bulk fuels require vent areas greater than ten times the limits in standards used for calculating vent areas. Also mentioned by James was the unforeseen consequences of “doing the right thing” related to gasification using steam-based inerting systems; characterisation of new fuels; “Legacy” safety cases and new fuels.

A paper by Miss Yee Sing Chin for the University of Leeds followed and was entitled “Ignition Risk from Biomass Dust Layers”. The paper was subtitled “Washing pre-treatment on low temperature ignition of biomass”. Yee began by summarising the situation in the UK about the importance of biomass as a fuel in power generation and some of its important differences in behaviour when compared with coal.

The motivation for this work was the number of reported incidents of fires related to biomass self-combustion and ignition of combustible biomass dust. A test methodology was used which measured two parameters for combustible dust, namely the Minimum Ignition Temperature (T_{LIT}) and the Maximum Permissible Surface Temperature (MPST). The determination of these parameters is specified by British Standard procedures.

The biomass samples were ground to -180 μm and then tested as received, after water washing and after acid digestion. The biomass samples were pine and miscanthus. Blends using 90% pine/10% miscanthus and 50% pine/50% miscanthus were prepared and tested. The experimental set up involved setting the hotplate at the estimated ignition temperature. The ring cavity was filled with ground biomass and levelled off all within 2 minutes. The timer and recorder were started once dust was levelled off. The ignition point was defined as the lowest temperature when a visible glow is seen ~ T_{LIT}. The experiments were repeated in multiples of 10°C using fresh biomass each time. The Ignition Delay Time is the time the recorder was started to the time a glow is observed t_{ig}. If no ignition is observed the experiment is repeated twice as confirmation allowing a wait for a minimum of 30 minutes between each test.

The biomasses and blends were tested then subjected to water washing and retested. It was found that the T_{LIT} increased by between 10 and 20°C after washing from around 330°C to around 350°C for the unwashed biomasses and from around 340°C to 350°C for the blends.

The biomasses were also subjected to acid digestion to estimate the effect of removing calcium and potassium on ignition temperature. More potassium was removed than calcium with 90% K removal found with miscanthus and 38% with pine. Around 18% Ca was removed from the miscanthus and only 3% from pine.

Thermogravimetric analysis was used to determine the level of risk where the activation energy EA ($kJ.mol^{-1}$) was plotted against T_{MWL} (°C) using a method developed at the University of Leeds (Jones, J.M. et al. 2015. Low temperature ignition of biomass. *Fuel Processing Technology.* **134**, pp.372-377). The samples tested in this work were found to exhibit a "High risk" of self-ignition. To apply this data to industrial practice a number of different criteria for MPST were compared. Treating the MPST as 75K less than T_{LIT} was the most lenient for thin deposits; 150°C was the most conservative for thin deposits. However, as dust thickness increases, the 150°C became the most lenient, opposite to when deposits are thin. MPST was less sensitive to material type as the dust layer thickness increased. The three BS curves were seen to converge as the dust thickness increased. There appears to be no hard and fast rule as to which method is the best – suitability depends on the application situation since a wide range of industry conditions exist.

Yee concluded her talk by stating that T_{LIT} of different species is confined within a narrow range; the removal of potassium by washing did make the fuel slightly safer with T_{LIT} increase but still showed high self-ignition risk after washing pre-treatment. Treating the MPST as 75K less than T_{LIT} was the most lenient for thin deposits and 150°C was most conservative for thin deposits; as dust thickness increases, the 150°C became the most lenient, opposite to when deposits are thin. MPST strongly depends on the situation, but regardless of this, thicker dust layers are more hazardous in terms of ignition risk.

The final paper before lunch was given by Professor Ed Lester of the University of Nottingham entitled "Fuel Ignition or Self Heating". Ed began by showing several increasingly alarming photographs of coal stock pile fires. We were then shown a map of the world with incidents of spontaneous coal fires both on and beneath the surface, the large number indicating the magnitude of the problem.

Ed then briefly reviewed early attempts to understand the causes of spontaneous combustion in coal. Many attempts using different approaches have been made; for example, the measurements of losses in transport and storage of coal (Porter et al 1910, Parr 1911 & 1925, Beagle 1925) were followed by adiabatic calorimetric studies (Davis et al 1925) to try to understand this phenomenon. Possible causes examined also included the effects of the sorption of oxygen (Carpenter 1966) and water (Davis 1926) on coal particles, the effect of increased surface area (Medek 2001), pyrite oxidation (Graham 1923, Parr 1925, Sujanti 1999) and finally bacterial action (Fuchs 1927, Coward 1957). Of more relevance was recent work done on the influence of moisture (Hodges et al.1964, Bhattacharya 1971) and oxygen (Hull et al 1995) and a multi-step reaction mechanism (Wang et al 2003). In addition, work aimed at predicting spontaneous combustion created a parameter known as the Crossing Point Temperature [CPT], (Banerjee 1966, Feng 1973, Chen 1995) and the self-heating rate test R70 index (Humphreys 1981). Differential thermal analysis (Marinov 1977, Pis et. al. 1996), and adiabatic calorimetry again featured (Davis 1925, Elder 1945, Gouws 1991) in attempts to understand this complex process. The continuing and varied approaches indicated that this was a difficult problem to solve.

Ed moved on to describe some of the work done by his group using thermogravimetric analysis (TGA) on a suite of 15 various world-wide coals. Each of the coals was subjected to TG analysis using a range of different heating rates from 5^{o}C/min to a maximum of 50^{o}C/min. The sample weight was monitored continuously and it is possible to produce plots of the rate of weight change with time/ temperature. The derivative of the change in weight versus time showed a linear portion for the different heating rates. When this data was plotted as dv/dt versus heating rate the linear part of the slope was found to indicate the reactivity of the different coals. This could be construed as being linked to the tendency of the coal to spontaneous ignite - the steeper the slope the more reactive the coal.

Ed then described some larger scale heating experiments in which a cylindrical column of coal (100g) was heated in a vertical furnace with thermocouples positioned to measure the coal temperatures at various points from the outer surface of the coal to the innermost core. Gas evolved from the sample was extracted from the top of the furnace and analysed and the mass of the sample was monitored continuously during the test runs. A series of so-called “transient temperature profiles” were obtained by plotting the temperatures of the thermocouples against time. Differences between the temperature in the centre and the temperature in the surface of the sample holder were influenced by the coal rank, water and volatile content. Processing of the data gathered from the whole sample suite enabled two distinct categories of coal to be identified. These were the coals most and least likely to spontaneously ignite. Data on some of the coals was less conclusive. The chars that remained after testing were examined using petrography and image analysis and were compared with the original coal.

A study of Indian coals was also briefly described. Samples of Chasnalla, Jitpur, Enna and Simlabahal coals, part of the Jharia coalfield, were examined as their spontaneous combustion behaviour was not as predicted using the CPT method. The newer large-scale heating tests combined with image analysis method devised by Ed’s team was found to give a better measure of the tendency of these coals to self-ignite. A similar exercise was briefly described in which samples of RDF which has self-ignited were tested and light on the likely causes was provided by this work.

It seems apparent that there is still more work to be done on this topic although newer technology may help to solve the question Fuel Ignition or Self Heating? The conclusions from this work were that some coals are naturally prone to self-heating; moisture is a key issue – adsorption and release mechanisms generate heat; some coals/biomass can self-heat as a result of transport, storage or mine architecture and self-heating is a complex set of mechanisms – both macro and micro.

Session 3 of the technical papers began after lunch with a talk by Jürgen Schaper of FCC Environment. Jürgen's presentation was entitled "Waste to Energy Industry View of Health and Safety Concerns". Jürgen began his talk on the Health & Safety concerns in the Energy from Waste (EfW) to energy sector by describing his involvement with to 147kt unit at North Hykeham in Lincolnshire. He summarised the design and actual operating data in which not all the design parameters had been met in its first campaign (2015). Output and export power had been lower than design and quantity of bottom ash and metals were higher than anticipated.

Safety concerns for EfW are influenced by fuel, process reagents and process by-products. Waste is the most diverse fuel imaginable with a vast range of sources and consistency. Types of waste which may be encountered in EfW systems are Municipal Solid Waste (MSW), C+I (Commercial and Industrial) waste, food waste, green/garden waste, biogenic waste – biomass' recycling waste, metals, Waste from Electrical and Electronic Equipment (WEEE) and liquids. Due to the very heterogeneous nature of the waste fuel the sampling must be done in an extensive and systematic way to obtain a representative and meaningful sample.

Waste materials may contain trace materials, some of which may be toxic, such as lead, cadmium, zinc, asbestos and PCB's, but they must all be burned. They may be very dry and combustible or very wet and difficult to ignite and burn. Jürgen suggested that in his view the best way to process waste in an EfW is to first perform a visual inspection from the crane seat and tipping hall as you cannot beat Eyeball Mk1!! Then, if it is oversized you shred it but look out for gas bottles!! Start to burn it before it starts to burn in your bunker, which has been known to happen.

Typical EfW combustion systems use either grate furnaces, fluidised bed systems or fluidised bed gasification systems. As far as process safety considerations are concerned one needs to understand that load and temperature control may vary significantly due to rapid changes in CV and moisture of the waste being burned. Oil or gas burners are used to compensate for temperature drops. A typical furnace would require around 30 minutes to 1 hour to burn its full bed of fuel. Shutdown conditions for which safety issue are important would be high CO levels in flue gas which would result from poor combustion. If a boiler tube leak occurs it is necessary to continue to feed water into the boiler until the fuel is burned off and/or ejected. Gas emissions into the boiler house could be a problem if furnace over-pressurisation occurs.

To avoid health and safety issues arising from contact with waste materials great attention should be paid to the maintenance and cleaning of contaminated equipment. The correct use of PPE i.e. masks, coveralls, overshoes, gloves, goggles, visors is important as is good hygiene and housekeeping in waste-affected area and the regular use of cleaning detergents and disinfection sprays. Continuous pest control i.e. rats, flies is also essential.

Many bulk process reagents are needed to operate the plant and all are subject to COSHH (Control of Substances Hazardous to Health) regulations. They include SNCR (Selective Non-Catalytic Reduction) reagents such as ammonia or urea solutions and flue gas treatment reagents such as hydrated lime and activated carbon, the latter being an additional fire risk. Care must clearly be taken in their use. Water treatment chemicals are generally the same as used in traditional power plants and no new risks are associated with their use. Process by-products include flue gas, incinerator bottom ash (IBA) and air pollution control residues (APCR).

Flue gas from waste combustion will have a chemical composition similar to any other combustion process, but with varying levels of chlorine, fluorine and sulphur, e.g. from plastics; varying levels of evaporated metals, e.g. cadmium, lead and aluminium; varying levels of CO, depending on combustion temperatures and O_2 levels in the furnace; ammonia and/or NO_x, if SNCR is not working correctly; dioxins/furans are unlikely but possible if 850° C is not achieved; high moisture, up to 25% H_2O and high dust levels. Untreated flue gas is highly acidic and fireside corrosion will occur on unprotected heat transfer surfaces and corrosion of steelwork is possible if the dew point is not exceeded. Flue gas can affect staff if sufficient suction is not maintained and can manifest itself through increased CO levels in the boiler house, dust release, which may contain heavy metals, and smell.

Treated flue gas may be compliant with IED/WID regulations after leaving the baghouse, but will still contain small levels of chlorine and sulphur; varying levels of CO, depending on combustion temperatures and O_2 levels in the furnace, NO_x, if SNCR is not working correctly; high moisture, up to 25% H_2O. This gas is still corrosive, but it is less of an issue.

APCRs are a mix of fly ash, limestone and activated carbon and are highly caustic with a pH > 12. They can contain traces of heavy metals and ammonia and are rated as Hazardous Waste which will need to be treated before disposal in a landfill. APCRs must be handled with care using enclosed systems and pneumatic conveying into a silo followed by disposal via road tanker. Normal procedures to handle toxic and caustic waste need to be applied.

IBA is a collection of fly ash from the boiler de-ashing grate or clinker system. It may contain 15 to 20% metals, some heavy metals and unburnt waste. All IBA is quenched in the ash discharger and stored wet in piles before it is transported off site. Risks associated with IBA are that it is caustic, pH ~12; it can contain heavy metals, but these are dispersed and diluted, so the material is non-toxic in most cases. IBA can contain waste, metals such as iron, aluminium and magnesium and water. Other safety issues with IBA are that it can release hydrogen and thereby generate local explosions. Jürgen then related process safety incidents with IBA. An explosion occurred in the hold of a general cargo vessel carrying incinerator bottom ash while at anchor off Plymouth 13th January 2017 in which one crew member was seriously injured. There have been various events in wet de-ashing systems of EfW plants worldwide over the last 20 years. The cause is that hydrogen gas is released from the IBA during the ageing process as aluminium reacts with calcium hydroxide and water to form aluminium hydroxide. Management of safety issues with IBA requires the application of DSEAR Regulations. This involves a DSEAR Assessment with fixed ash discharger ventilation, building ventilation and hydrogen sensors if accumulations are possible. One should aim for only short-term storage either inside or outside any buildings and adopt pH management in the ash discharger. The risk is manageable and therefore no longer judged to be a serious issue.

Management of ashes in general requires frequent sampling and analysis to prove levels of toxicity and consistency and for reporting to the EA, together with the gaseous emission declarations. As it is waste and falls under the Duty of Care process it must be fully monitored with waste transfer notes and consignment notes. IBA is recovered to extract aggregate and metals for use in the construction and steel industries and is an established process in line with EA protocols

In conclusion Jürgen summarised his talk by commenting that process safety in waste burning plant is comparable to the operation of small solid fuel fired boiler plant. Fuel consistency (or variability) introduces a vast spectrum of additional chemical risks which must be addressed. Process by-products need careful consideration due to chemical consistency and housekeeping and Health & Safety control is essential to maintain a safe environment like any other plant.

Dr Brian Crook of the Health & Safety Laboratories at Buxton spoke about "Bioaerosols Associated with Biomass to Energy – Worker Exposure and Health Hazards". Bioaerosols, (short for biological aerosols), are aerosols which contain biologically active material such as bacteria, fungi and other potentially hazardous materials. Bioaerosols are always naturally present from various sources such as dust, water, vegetation and animals. They range in number and predominant species depending on seasonal, geographic and local sources. They are further influenced by human activities such as agriculture, construction and vehicles. It is recognised that there is a need for more data on bioaerosol emissions associated with bulk biomass to energy conversion.

The current challenges in the biomass-to-energy industry include the **a**doption of 'new' processes after years of 'coal-only' and that not only dust but also biological components now exist which require new risk assessment approaches. Rohr et al (2015) identified that "potential occupational health impacts of biomass combustion in power generation remain poorly defined".

Why are bioaerosols a problem in biomass waste to energy? Biomass can provide nutritional and physical requirements for microbial growth. Fungi and bacteria are naturally present in biomass and the conditions of food, water and temperature lead to their multiplication. In addition, movement of biomass generates bioaerosols. Why are we concerned about bioaerosols and health? There are no occupational exposure limits, there is limited dose-response data but there is evidence as a potential respiratory hazard. The implication is that this hazard should be under COSHH control to "As low as reasonable practical" (ALARP).

Brian then focused on two particular waste and recycling bioaerosols which impact health, namely: *Aspergillus fumigatus* and *endotoxin*. It is known that workers are exposed to bioaerosols and due to dispersion neighbours, i.e. other workplaces, passers-by, residents may be affected. Why are we concerned about *Aspergillus fumigatus*? It is a prolific spore producer and the spores are respirable. It is also an allergen and an opportunist pathogen. Why are we concerned about *endotoxin*? It is Gram –ve bacterial cell wall, immunotoxic and can cause inhalation fever.

In a Danish biofuel plant study by Madsen in 2006 data was reported on workers' personal exposure to inhalable airborne fungi, bacteria, *endotoxin* at five biofuel plants. It was found that total bacteria - median = 4.8×10^5 cells/m^3; total fungi - median = 2.1×10^5 spores/m^3; and *endotoxin* - median = 55 EU/m^3. Exposure levels differed between the plants and this was attributed to different process equipment, different tasks and the biofuels handled. For example, *endotoxin* higher concentrations at straw plants than at wood-chip plants, while the fungus *Aspergillus fumigatus* greatest concentration at wood-chip plants. It was also noted that *endotoxin* was found to be in significant concentrations in all size dust fractions (Madsen and Nielsen, 2010).

There are also indirect microbiological hazards from stored wood. Microbiological activity in stored wood can release volatile chemicals and carbon dioxide leading to oxygen depletion in confined spaces and an asphyxiation hazard.

An HSL study data by Simpson et al 2016 investigated small scale storage of wood pellets and chips for community/domestic use (6 sites) and one pellet warehouse. It was reported that wood chips were more microbiologically contaminated than pellets and that the combination of chemical decomposition and microbial activity could create oxygen depleted atmospheres in confined spaces.

Other unpublished HSL study data looked at palm kernel and olive pulp imported into UK and used either for animal feed or biomass for co-firing with coal. These materials were very susceptible to microbial colonisation and there was evidence of visible microbial growth and clumping of material in automated feed. *Aspergillus* and *actinomycetes* were isolated from the samples tested.

It is very important that monitoring of dust and bioaerosol measurement in biomass to energy processes is carried out. This may consist of personal sampling which measures health relevant exposure measurement in breathing zone; fixed point sampling which gives a general overview of emissions and identification of source. The samples will provide a simple culture-based analysis with enumeration and characterisation of species and also data to support risk assessment. Brian presented some data from the MRF (Metal Recycling Facilities) which resembles biomass processing and use. These include materials reception; some automatic sorting, although manual sorting still common, and that some LEV's exist but not in all cases.

An HSL study in MRFs detailed occupational hygiene surveys at seven MRFs. Each visit aimed to measure task-related exposures to dust and bioaerosols at all stages of the recycling process mainly by personal monitoring. In addition, exposure control strategies were assessed including management systems (COSHH assessments, operator training etc.), engineering controls and the PPE regime. The results obtained showed that workers' potential microbial exposures were significant. Exposure to inhalable bacteria was up to 10^5 cfu/m^3 and 73% of the samples were greater than 10^4. Exposure to inhalable fungi was up to 10^5 and 81% samples were greater than 10^4. Exposure to *Aspergillus fumigatus* was up to 10^5. 12% samples were greater than 10^4 and a further 14% were greater than 10^3 ; *endotoxin* levels were up to 2,399 EU/m^3; 34% above the proposed limit of 90 EU/m^3 and mostly associated with high energy sorting machinery.

Brian also showed a table illustrating the potential exposure and health risks associated with biomass-related power generation. The table included job type, tasks and potential exposures. The full paper from which this table is taken can be accessed from this link: - http://www.mdpi.com/1660-4601/12/7/8542/htm A measure of protection in biomass operations is afforded by vehicle cabs. To demonstrate this the team measured bioaerosols inside and outside vehicle cabs. Bioaerosol levels were reduced inside vehicle cabs and although the effect was variable a median value of a four-fold reduction was recorded. This finding suggested that there is a need for further examination of these benefits.

Cleaning and maintenance can be a significant contributor to air-borne dusts and this must be recognised as involving a different set of operators such as cleaners, maintenance engineers or outage contractors. An example of this was a case study carried out on a brick-making plant. Respirable crystalline silica exposure was measured at 0.83 mg/m^3 for a 70 minute sample. This was enough to exceed 8 hour TWA (Time-weighted average) WEL (Working exposure limit). It was found that the cleaning operation contributed 45 % of daily dose – no RPE (Respiratory protective equipment)! A further case study on a waste and recycling plant found that the company assessment under-estimated risk because it did not include end of shift clean down. It was found that task-specific dust exposures at other plants were greater than 100 mg/m^3 during cleaning.

HSL are currently measuring bioaerosol exposure for different worker shifts in biomass handling, municipal waste transfer stations and mechanical-biological treatment plant materials handling areas. At one plant, they compared day shift routine work with night shift cleaning and maintenance. For daytime shifts: *endotoxin* from 127 -210 EU/m^3; bacteria $4.0 \times 10^3 – 4.4 \times 10^4$ cfu/m^3; fungi $8.0 \times 10^4 – 1.0 \times 10^5$ cfu/m^3. For night-time: *endotoxin* from 117 - 1040!! EU/m^3; bacteria $2.6 \times 10^4 – 3.6 \times 10^5$ cfu/m^3; fungi $1.1 \times 10^5 – 4.0 \times 10^5$ cfu/m^3. The end of night time cleaning operation clearly increased to exposure to workers of biohazardous materials. Effective LEV for dust & bioaerosol removal is essential due to microbiological activity in stored wood releasing bioaerosols, volatile chemicals, carbon dioxide and oxygen depletion in confined spaces and asphyxiation hazard.

It was recommended that the use of smoke machines to assist LEV measurement should be adopted. Smoke is an excellent way of visualising complex and turbulent airflow patterns whether in an open or enclosed space. A review of smoke machines is available at www.hse.gov.uk or search for fog machines on the internet.

In summary, Brian highlighted some take away thoughts as follows: - Bioaerosol emissions associated with bulk biomass to energy – we need more data; there is some read-across from previous exposure assessment to dust and bioaerosols in waste and recycling; we need to assess the controls that are in place and what can be done to mitigate exposure; do not forget to assess maintenance work exposure; look at WISH Forum Bioaerosols Group where simple generic guidance is being drafted.

Professor Jennifer Wen of the University of Warwick was next up with her paper entitled "Consequence Analysis of Fire and Explosion Hazards with Potential Applications to the Power Generation Sector". Professor Wen heads a multidisciplinary research laboratory, (known as Warwick FIRE), which performs both fundamental and applied research into fire and explosion hazards as well as accidental release of hazardous materials. Warwick FIRE aims to provide answers to cross-cutting safety issues related to energy, buildings and the environment. The laboratory was formed by Professor Wen in May 2013 following her move to the University of Warwick from Kingston University London, where she established and led the world-class Centre for Fire and Explosion Studies for over 10 years.

A snapshot of current activities at Warwick was described and included the modelling of spontaneous ignition in pressurised hydrogen releases; fire modelling using a modified form of FireFOAM® and explosion modelling using a modified version of OpenFOAM®. Explosion modelling included investigations into vented explosions and Deflagration-to-Detonation Transitions (DDTs).

The motivation to study pressurised hydrogen releases stems from the increasing use of hydrogen in cars, in fuel cells and as a fuel in liquid form for rocket launches. Professor Wen's team uses a variety of numerical models to solve the several complex and separate stages in this process.

Fire modelling using a modified form of FireFOAM® has been applied to the study of façade fires, for modelling flame speed, hydrogen jet fires and enclosure and syngas fires. Vented explosion modelling has also been undertaken using a modified version of OpenFOAM®. In this case the motivation for the study has been the use of hydrogen cylinders fitted into racks inside ISO containers in hydrogen energy applications.

Flame acceleration and DDT in hydrogen/air mixtures with concentration gradients has also been investigated. The driver for this work is the accidental release of combustible gas mixtures. These releases are usually inhomogeneous in nature and are subject to both vertical and horizontal concentration gradients.

Professor Wen ended her talk by summarising her findings as follows: the KIVA-3V CFD code has been modified to simulate spontaneous ignition in pressurised hydrogen releases; OpenFOAM®, an open source CFD code, has been modified by Warwick FIRE for the following applications: jet fires, flame spread and coupled fire and mass burning rate studies; explosion modelling using modified OpenFOAM®; vented explosions; deflagration to detonation transition (DDT) and hydrodynamic instabilities during flame acceleration and DDT.

The second presentation from RJM International was given by Steve Cornwell and was entitled "Operational Hazards Associated with Coal Fired Boilers; Design Requirements of Safety Control Systems". Steve began by discussing power station safety fuel issues. Areas for concern are fuel storage – bulk store and bunker house, conveyors, mills, PF systems, burners and furnace, air heaters and draught plant. Steve accepted that this was not an exhaustive list as all plants are different, but for this presentation, he intended to focus on combustion safety issues, principally the boiler.

Two important definitions are "hazard" – anything that can cause harm and "risk" - the chance, high or low, that somebody could be harmed by these hazards, with an indication of how serious the harm could be. Safety analysis will encompass both of these to develop a suitable protection system. The evaluation must account for specific site features – fuel, burner design, use of over fire air (OFA) or flue gas recirculation (FGR).

Combustion safety tools are available for use and comprise:- Codes and Standards – *used for general guidance and best practice,* Hazard Identification – *site specific identification of hazards present,* HAZOP – *established procedures based on nodes and key words – 'more flow', 'less flow' etc.,* Layers of Protection Analysis – *quantitative assessment of individual risk to compare with numerical risk target (ALARP).*

Several Standards and Codes of Practice are available and some are better than others, however, they are not always consistent. A much-used standard is NFPA 85 Boiler and Combustion System Hazards Code. Nevertheless, f*ollowing a code does not guarantee safety – site specific factors must be analysed.* NFPA includes detailed guidance on oil, gas and coal; different boiler types (PF boiler, fluidised bed). It includes flue gas desulphurisation (FGD)/ SNCR/SCR/FGR hazards, guidance for different fuels and standard piping and instrumentation (P&IDs), interlock lists etc.

Coal-fired boiler hazards are often combustion related. The principal boiler hazard is the *ignition of accumulated unburnt fuel, leading to a pressure rise that is sufficient to breach containment of the boiler casing*, resulting in the expulsion of hot gases, materials and structural components. Combustion safety system is intended to prevent this.

Steve presented a table of fuel hazards which were related to boiler start-up, burner start-up, mill start and those which might occur during normal operation. For boiler start-up, a hazard would be leaking gas from igniters or oil from burners which accumulated in the furnace. A burner start-up hazard would be failed ignition on the first burner(s) which would release pulverised fuel into the furnace. A mill start-up hazard would be lean fuel/air mixture at a burner or failed/unsupported ignition which may release fuel into the furnace. This would be a greater hazard for the first mill setting. A hazard which could occur during normal operation would be flame instability. This could be caused by restriction or loss of coal feed, wet or poor quality coal or by a control system error. Steve provided details of how to mitigate against these hazards but which are not included in this report (but can be seen in the presentation on the FERF website).

Flame detection is an integral part of a combustion safety system. Although it sounds simple, it can be complex to implement. A flame monitor should detect a flame and act on loss of flame whatever the cause of the flame loss. A flame monitor must detect the presence and absence of the flame on it's burner but not detect flames on nearby burners (flame discrimination). It must not respond to hot/glowing refractory, it must be reliable (self-checking capability) and work in a cold and hot boiler. Modern units are becoming increasingly complex.

To enable tuning, many flame adjustments are possible such as frequency response, gain, threshold settings. There are usually multiple settings for different boiler conditions. Using flame flicker enables the monitor to see near flame and ignore flames further away. The higher frequency of the main part of the flame is detected whilst the lower frequency would be ignored. This design feature is intended to differentiate flames. The ability to adjust the orientation of the flame monitor is important here. The instrument is only one part of the system – how should the output be used?

Flame detection in practice is complex; for example, in a modern boiler there might be 48 burners with 6 burners per mill and 36 required for full load (6 mills). Individual burners cannot be shut down, only mill groups (6 at a time). For a significant accumulation of unburnt fuel, sufficient time must be provided before ignition and the spatial spread of burners is important. With 6 burners on mill 1 – how many flame losses to trip a mill: 1 flame? 2 flames? 4 flames? The same number irrespective of mills in service? Flame detection logic is a complex area and the risk of fuel accumulation is higher during start-up with fewer mills in service. There are not as many sources of ignition in boiler but different boilers have different mill configurations, which have different requirements and there is little guidance for this. Being over-conservative would lead to unnecessary mill trips but alternatively being under-conservative would introduce safety risks.

Control system design makes use of a standard, IEC 61508, which is applicable to safety-related programmable systems. It is based on a quantified risk analysis, it determines the reliability requirements of a control system to act correctly on demand. The higher degree of risk reduction required of the system, the more reliable it must be. It establishes the design, testing and maintenance requirements of a control system and IEC 61508 introduces the concept of Safety Integrity Levels (SIL). Based on the probability of 'dangerous failure on demand' for a safety function (how likely is the system to work when needed') and ranked from 1 to 4. SIL 1 is lowest integrity, 4 is highest and for furnace protection, SIL 1 – 2 is most applicable. Assessment is generally carried out by layers of protection analysis based on individual risk.

Steve ended his talk by saying that hopefully, he had provided an introduction to combustion safety and highlighted the complexities of loss of flame protection and flame detection. He also gave a very brief introduction to SIL. As a final point, Steve said that suitable and sufficient analysis is required for each scenario.

Professor Yong Yan of the University of Kent then reviewed progress in his teams work on the very important topic of flame measurement with a paper entitled "Flame Stability Monitoring through Digital Imaging".

Professor Yan began by explaining that unstable flames are a recognised problem in fossil fuel fired combustion processes where low-quality fuel, the use of fuel blends and co-firing of biomass with fossil fuel are widely practised. The problem is exacerbated by the need for flexible operation of power plants involving operating at lower load and with load cycling. Unstable flames can produce many combustion problems such as vibration of the furnaces (with its safety implications), reduced combustion efficiency, high NOx and high unburnt carbon emissions. In addition, the non-uniform thermal distribution in the flue gas can result in increased wall thermal stress. The risks associated with the use of conventional flame-eye and flame scanners for the monitoring of complex flames are well known and power plant operators need to consider the installation of advanced flame monitoring systems.

The challenges in the design of an advanced flame monitoring system are the high temperature environment, the presence of dust contamination and vibration. A successful flame monitor must be robust and compact, operate in real-time and be multi-functional. Important features that must be addressed in any successful flame monitoring methodology include the quantitative assessment of flame stability, burner condition monitoring, emission prediction and on-line fuel tracking (identification).

Data on the characteristics of flames is very important and includes; size (area, length etc.); brightness; non-uniformity; flame front; oscillation frequency *(from photodiodes or high-speed videos*); temperature (mean, highest and distribution); colour information *(HSI and RGB)*; entropy (flame internal structure) and stability index.

Professor Yan then showed diagrammatically the principles of designing an advanced flame monitoring system. The basic components consist of an optical fibre probe which monitors the flame and is connected to an imaging and signal processing unit. The first process is to split the beam of light with part of it entering a photodiode system and the remainder into a digital camera. The photodiodes pass visible and IR radiation into a system of photodetectors and a signal processing board for oscillation frequency measurement. The digital camera output is fed into a device to measure luminous parameters and temperature. The combined data from both systems is fed into a device known as a Flame Stability Index (FSI) unit and thence to a PC.

Professor Yan's team have experimentally investigated two generalised methods. The first method uses the combination of the standard deviations of seven parameters such as the colour, geometry, and luminance extracted from flame images in HSI colour space. The second method uses twenty parameters extracted from flame images such as temperature, non-uniformity, entropy, oscillation frequency and a colour space model HSI (Hue, Saturation and Intensity). The FSI has been assigned values from 1, which indicates a perfectly stable flame, to 0 which is an extremely unstable flame. The oscillation frequency is derived from the spectral analysis of flame radiation signals. The measurements involved in these two methods do not require prior knowledge about fuel property, burner type, and other operation conditions. They can therefore be easily applied to flame stability assessment without costly and complex adaption. The method is computationally simple and suitable for on-line measurement.

Experimental trials were carried out on a 9-MW heavy-oil-fired combustion test rig over a wide range of combustion conditions including variations in swirl vane position of the tertiary air, swirl vane position of the secondary air, and the ratio of the primary air to the total air. The impact of these burner parameters on the stability of heavy oil flames was investigated and the experimental results obtained demonstrated the effectiveness of the methods and the importance of maintaining a stable flame for reduced NOx emissions.

Further trials were carried out using a 660MW unit firing heavy fuel oil, a 915MW unit firing coal and coal/ biomass; a 520MW coal-fired boiler and a 250kW test facility at PACT. The spectral data from biomass firing explained why the existing flame eye monitoring system designed for coal failed when applied to biomass firing. It is envisaged that such methods can be easily transferred to existing flame closed-circuit television systems and flame failure detectors in power stations for flame stability monitoring.

A novel and potentially very useful method of monitoring biomass in bulk storage was briefly mentioned by Professor Yan. It involves the use of acoustic tomography and requires an array of speakers and microphones (sound transducers) located above the silo of biomass.

In conclusions, Professor Yan summarised his talk by saying that an advanced flame monitoring system has been developed for long-term operation on full-scale combustion plants and test rigs. Extensive field trials have been conducted on full-scale power plants to assess the operability and effectiveness of the system. The results including flame stability index are encouraging and have been useful in helping to understand and optimise the difficult and complex combustion processes. Making the flame monitoring system cost-effective, robust and reliable has, however, been a challenge.

The final paper of the day was given by Oscar Farias Moguel of the University of Sheffield entitled “On the Prediction of Flame Stability: Estimation of the Characteristic Flame Frequency under Air and Oxy Fuel Conditions”.

The objectives of Oscar’s work were to evaluate the oscillatory nature of the flame by LES simulations using instantaneous values of different scalars and image and data processing.; and to obtain a trend for the flame dynamics under different oxy-fuel conditions, i.e. air and 21, 25, 30% oxygen. The test facility used for this work was the 250kW PACT rig firing pulverized coal under air and Oxy fuel firing conditions.

The project objectives were achieved and Oscar was able to show that LES instantaneous results were successfully used to characterise the flame and Oxy-fuel flames showed lower flicker frequencies in comparison to the air-fired case. A trend was also shown for the flame dynamics under different oxy-fuel conditions. Ongoing and further work includes the evaluation of the turbulent coherent structures development in the furnace and their impact on the flame oscillation; the development of the mathematical model for the propagation of pressure waves in confined spaces and an assessment of flame stability for different fuels.

The technical sessions closed at around 4.30pm and the concluding remarks were made by Dr Will Quick of Uniper (FERF Chairman – Industry). He thanked the authors for their varied and interesting contributions in what for many of us was a technical departure from our normal ‘day job’.

Newsletters and Journals from other organisations

News items from recent issues of the Carbon Capture Journal may be downloaded from this link:- http://www.carboncapturejournal.com/AllNews.aspx

EU Energy Focus E-mail Bulletin for July 2017 can be found here: http://communityenergywales.org.uk/eu-energy-focus-bulletin/

COAL HUB is an online information platform for news, analysis, events and information on the global COAL industry. By accessing its website http://www.thecoalhub.com/. In May and June of 2017 the following reports were available for download:- The Future of Reliable Clean Coal Power; Coal in a Rapidly Changing Energy Landscape; Coal-fired Generation in Australia; The Roel Of Clean Coal Technology in Japan and Can Gas Displace Coal in Europe.

News alerts in coal and energy research

New owner for recycling and organics monitoring products

CompostManager and PreventIt, monitoring solutions for the recycling and organics industries, are now wholly owned by Freeland Scientific Limited. CompostManager measures variables such as temperature, moisture, oxygen and carbon dioxide within composting piles. The information enables site productivity to be improved and reduces odour problems. It is a key tool for meeting legislative and environmental requirements and adopting Best Available Techniques (BAT) and odour management plans.

PreventIt is a low-cost fire prevention solution for the waste and recycling industry and enables operators to comply with the Environment Agency’s new Fire Prevention Plan requirements and the Waste Industry Safety and Health (WISH) guidance. PreventIt monitors temperatures in material stockpiles and activates an alarm if they rise too high, allowing the operator to take action to avert a fire.

Freeland Scientific is a new division of Freeland UK, one of the original partners behind the products. “The new streamlined ownership enables faster decision making and a commitment to development so we continue to offer the best available solutions to site operators,” managing director, George Longmuir, explained. Dr Eric Crouch continues to manage technical support and development of the products. Sales and administration of CompostManager and PreventIt have been consolidated at Freeland’s head office in Hextable, Kent. Manufacturing and development activities have moved to a new site in Robertsbridge, East Sussex. The telephone number for all enquiries is 01322-667076, or visit www.freelandscientific.com.

Summaries from the Technical Press

Please be aware that links to some of the news articles are not retained on the web indefinitely. Consequently, links which were active when the newsletter was written may, in time, become unavailable.

'It's distorting the whole energy market' Britain to scrap EU's green targets post-Brexit

15th April 2017, Ross Logan, Express

The Renewable Energy Directive is thought to be among of raft of EU policies set for the post-Brexit bonfire of Brussels diktats, Government insiders have suggested. The directive sets targets for each EU member state for the production and promotion of energy from renewable sources such as solar and wind.

Britain's current target is to generate 15 per cent of all energy from renewable sources by 2020 - a figure it is likely to miss, resulting in fines. Critics say the policy is distorting, as the targets only look at energy generated and not efficiencies made. It's also resulted in the Government spending billions on subsidies for wind and solar farms which are ultimately paid for by customers through energy bills. For more:-
http://www.express.co.uk/news/uk/792341/Britain-to-scrap-EU-s-green-targets-post-Brexit

India's outsized coal plans would wipe out Paris climate goals

25th April 2017, unattributed, ScienceDaily

India will not be able to meet its Paris climate agreement commitments in the coming years if it carries through with plans to construct nearly 370 coal-fired power plants, according to University of California, Irvine and CoalSwarm researchers. For more visit:-
https://www.sciencedaily.com/releases/2017/04/170425140207.htm

Discovery of a facile process for hydrogen production using ammonia as a carrier

29th April 2017. Unattributed, ScienceDaily

Hydrogen (H_2) has attracted considerable attention as a clean energy source because the only by-product of its reaction with oxygen is water, and high efficiency for energy conversion is achieved when it is combined with fuel cell technologies. However, low volumetric energy density and the dangers of transporting and handling H_2 are drawbacks for commercial applications. These problems could be eliminated by using ammonia as a H_2 storage medium (H_2 carrier). For more visit:-
https://www.sciencedaily.com/releases/2017/04/170429095031.htm?utm_source=feedburner&utm_medium=email&utm_campaign=Feed%3A+sciencedaily%2Fmatter_energy%2Ffossil_fuels+%28Fossil+Fuels+News+--+ScienceDaily%29

New catalyst for water splitting developed

3rd May 2017, unattributed, ScienceDaily

Water-splitting systems require a very efficient catalyst to speed up the chemical reaction that splits water into hydrogen and oxygen, while preventing the gases from recombining back into water. Now an international research team has developed a new catalyst with a molybdenum coating that prevents this problematic back reaction and works well in realistic operating conditions. For more visit:-
https://www.sciencedaily.com/releases/2017/05/170503132336.htm

Independent energy generators turn to battery storage to drive renewable energy revolution

3rd May 2017, unattributed, Energy & Environment Management

Energy entrepreneurs outside the traditional supply sector are turning to battery storage and winning four fifths of long-term battery contracts to provide grid services. The increased

investment in battery storage from independent energy generators is set to increase commercial UK battery capacity 100 times by 2020, according to innovative energy company SmartestEnergy in their fifth annual *Energy Entrepreneurs Report*. For more visit:-
http://www.eaem.co.uk/news/independent-energy-generators-turn-battery-storage-drive-renewable-energy-revolution

Just 1% of UK 'strongly opposed' to renewables, finds government survey

4th May 2017, Ian Johnston, The Independent

Just 1 per cent of the public are "strongly opposed" to renewable energy, according to a new Government survey. The poll found a further 4 per cent were simply "opposed" to solar, wind and other such forms of electricity generation, but both groups were massively outnumbered by supporters of renewables. Some 79 per cent said they were in favour of clean and green energy, a figure close to the 71 per cent who said they were "very or fairly concerned" by climate change. For more visit:-
http://www.independent.co.uk/environment/uk-renewables-energy-sources-oppose-one-per-cent-government-survey-solar-power-wind-a7717106.html

UK achieves solar power record as temperatures soar

26th May 2017, unattributed, BBC Business

A record amount of solar power was generated on Friday as Britain basked in sunshine and temperatures of up to 28C, the National Grid has said. It said 8.7 gigawatts (GW) had been generated at lunchtime, representing 24.3% of total generation across the UK. The level tops the previous record of 8.48GW set on 10 May.

Duncan Burt, head of control room operations at National Grid, called it the "beginning of a new era". "We now have significant volumes of renewable energy on the system," he said. "We also have the tools available to ensure we can balance supply and demand." Alongside the contribution from solar, 23% of power came from nuclear sources, 30% from natural gas and just 1.4% from coal. Wind, hydro power and biomass were also used. For more visit:-
http://www.bbc.co.uk/news/business-40058074

Where rivers meet the sea: Harnessing energy generated when freshwater meets saltwater

26th May 2017, unattributed, ScienceDaily

Penn State researchers have created a new hybrid technology that produces unprecedented amounts of electrical power where seawater and freshwater combine at the coast. "The goal of this technology is to generate electricity from where the rivers meet the ocean," said Christopher Gorski, assistant professor in environmental engineering at Penn State. "It's based on the difference in the salt concentrations between the two water sources."

That difference in salt concentration has the potential to generate enough energy to meet up to 40 percent of global electricity demands. Though methods currently exist to capture this energy, the two most successful methods, pressure retarded osmosis (PRO) and reverse electrodialysis (RED), have thus far fallen short. For more visit:-
https://www.sciencedaily.com/releases/2017/05/170526144034.htm

We can't count on trees to solve our global warming mess — there's just too much CO_2 out there

29th May 2017, Tibi Puiu, ZME Science

Massive reforestation can't save us from runaway global warming, despite what intuition might tell us. According to a recent study which simulated CO2 removal from a biosphere point of view, biomass plantations would be inadequate in steering us away from a potentially disastrous 2 degrees Celsius global warming scenario. Instead, we have to cut off fossil fuels immediately *and* plant biomass at the same time if we're to have a winning shot at this. For more visit:
http://www.zmescience.com/ecology/climate/trees-cant-save-us/

Trump pulls out of Paris agreement

2nd June 2017, Anna Simet, Biomass Magazine

In what he described as a move to fulfil his duty to protect America and its citizens, President Donald Trump has officially begun the process to withdraw the U.S. from the Paris Climate Accord. In at a June 1 White House press conference, Trump officially announced his decision, stating that he was open to begin negotiations to re-enter on different terms, or initiate an entirely new transaction on terms that are "fair to the U.S., its businesses, its workers, its people, its taxpayers. So we're getting out," he said. "But we will start to negotiate and we'll see if we can make a deal that's fair. If we can, that's great. If we can't, that's fine." Trump used American jobs as the cornerstone of his speech, deeming the Paris agreement as a policy that disadvantages the U.S. and will result in the loss of jobs, lower wages, shuttered facilities and "vast economic reduction," that would impose "draconian financial and economic burdens" on the U.S. For more visit:-
http://biomassmagazine.com/articles/14425/trump-pulls-us-out-of-paris-agreement

Advances in splitting CO_2 could lead to a new source of clean fuel

6th June 2017, Eva Hershaw, Seeker.com

Scientists in Switzerland have found a new way to split carbon dioxide using a low-cost copper catalyst in a system driven by solar power. The process is carbon neutral, efficient, and may be a first step towards creating a carbon-based fuel made with CO_2 captured from the atmosphere. The system, described in an article published by *Nature Energy*, was able to split carbon dioxide into oxygen and carbon monoxide — which can be used to create liquid fuel — at a rate of 13.4%. "It's the highest value that has been reported," said Marcel Schreier, a chemical engineer and lead author on the study out of Ecole Polytechnique Fédérale de Lausanne (EPFL). "Everyone in this field is interested in seeing how far we can go with what we have." For more visit:-
https://www.seeker.com/earth/energy/advances-in-splitting-carbon-dioxide-could-lead-to-a-new-source-of-clean-fuel

Climate exit deal could hit U.S. pellet exports

6th June 2017, unattributed, Canadian Biomass Magazine

President Donald Trump's plan to withdraw from the Paris climate accord could have huge consequences for the U.S. wood pellet exporting industry post-2020. The U.S. not being part of the Paris agreement will make it difficult for wood pellet producers to export to E.U. markets after 2020, if the E.U.'s proposed renewable energy directive is passed in its current form. The directive proposes that if forest biomass is to contribute to a E.U. member state's renewable energy targets then it must come from countries which have ratified the Paris agreement. For more visit:-

https://www.canadianbiomassmagazine.ca/pellets/climate-exit-deal-could-hit-us-pellet-exports-6305

Renewables provide more than half UK electricity for first time

8th June 2017, Roger Harrabin, BBC News

Renewable sources of energy have generated more electricity than coal and gas in Great Britain for the first time. National Grid reported that, on Wednesday lunchtime, power from wind, solar, hydro and wood pellet burning supplied 50.7% of UK energy. Add in nuclear, and by 2pm low carbon sources were producing 72.1% of electricity in Great Britain. Wednesday lunchtime was perfect for renewables being both sunny and windy. Records for wind power are being set across Northern Europe. The National Grid, the body that owns and manages the power supply around the UK, said in a tweet: "For the first time ever this lunchtime wind, nuclear and solar were all generating more than both gas and coal combined." For more visit:- http://www.bbc.co.uk/news/business-40198567

The way toward cleaner coal plants

9th June 2017, unattributed, ScienceDaily

New landmark in modeling turbulence, paving the road to better power plant modelling and design. In an effort to design cleaner coal power plants, researchers have performed some of the most detailed multiphase turbulence simulations ever run. A team of researchers at RWTH Aachen University's Institute of Aerodynamics (AIA) has long been interested in using computation to understand turbulence -- one of the major challenging mysteries of fluid dynamics -- and how it relates to aircraft noise, fuel efficiency, or the transport of pollutants, among other research interests.

The team has been using the Cray XC40 Hazel Hen supercomputer at the High-Performance Computing Center Stuttgart to study turbulent multiphase flows -- the movement of two materials in different states (such as solids and liquids) or materials in the same state that, for chemical reasons, cannot mix (such as oil and water). The team is also working to improve the accuracy of turbulence simulations on more modest computers. For more visit:- https://www.sciencedaily.com/releases/2017/06/170609102246.htm

New form of carbon that's hard as a rock, yet elastic, like rubber

9th June 2017, unattributed, ScienceDaily

Carbon is an element of seemingly infinite possibilities. This is because the configuration of its electrons allows for numerous self-bonding combinations that give rise to a range of materials with varying properties. A team of scientists has developed a form of ultrastrong, lightweight carbon that is also elastic and electrically conductive. A material with such a unique combination of properties could serve a wide variety of applications from aerospace engineering to military armour. For more visit:- https://www.sciencedaily.com/releases/2017/06/170609193112.htm

Demo plant produces renewable fuel from CO_2 captured from the air

9th June 2017, unattributed, ScienceDaily

The unique Soletair demo plant developed in Finland uses carbon dioxide to produce renewable fuels and chemicals. The aim of the project is to demonstrate the technical performance of the overall process and produce 200 litres of fuels and other hydrocarbons for research purposes. This concerns a one-of-a-kind demo plant in which the entire process chain, from solar power generation to hydrocarbon production, is in the same place. For more visit:-

https://www.sciencedaily.com/releases/2017/06/170609103828.htm

Plastic made from sugar and carbon dioxide

13th June 2017, unattributed, ScienceDaily

Some biodegradable plastics could in the future be made using sugar and carbon dioxide, replacing unsustainable plastics made from crude oil, following research by scientists from the Centre for Sustainable Chemical Technologies (CSCT) at the University of Bath. For more visit:-
https://www.sciencedaily.com/releases/2017/06/170613111639.htm

Solar material for producing clean hydrogen fuel

14th June 2017, unattributed, ScienceDaily

A new material has been created based on gold and black phosphorus to produce clean hydrogen fuel using the full spectrum of sunlight. A team in Osaka University has developed a material to harvest a broader spectrum of sunlight. The three-part composites of this material maximize both absorbing light and its efficiency for water splitting. The core is a traditional semiconductor, lanthanum titanium oxide (LTO). The LTO surface is partly coated with tiny specks of gold, known as nanoparticles. Finally, the gold-covered LTO is mixed with ultrathin sheets of the element black phosphorus (BP), which acts as a light absorber. For more visit:- https://www.sciencedaily.com/releases/2017/06/170614092607.htm

Solar paint offers endless energy from water vapor

14th June 2017, unattributed, ScienceDaily

Researchers have developed a solar paint that can absorb water vapour and split it to generate hydrogen -- the cleanest source of energy. The paint contains a newly developed compound that acts like silica gel, which is used in sachets to absorb moisture and keep food, medicines and electronics fresh and dry. But unlike silica gel, the new material, synthetic molybdenum-sulphide, also acts as a semi-conductor and catalyses the splitting of water molecules into hydrogen and oxygen. For more visit:-
https://www.sciencedaily.com/releases/2017/06/170614091833.htm

Drax says may convert coal units to run on gas

15th June 2017, Karolin Schaps, Euronews

British power producer Drax is assessing whether to convert its remaining coal-fired power units to run on gas instead so they can compete in the country's annual capacity auction, the company said on Thursday.

Drax has converted half of its Yorkshire coal plant, once Europe's most polluting coal-fired power station, to burn wood pellets but plans to switch the remaining units to biomass have stalled since the government changed renewable energy subsidies. "One option is to repurpose the coal units to run on gas," said Andy Koss, chief executive of Drax's generation business, during a presentation to analysts.

The plans are in the early assessment stage but Drax Chief Executive Dorothy Thompson said the type of gas plant conversion being considered would mean the units would qualify to compete for 15-year contracts in Britain's annual capacity auction. Drax is banking on the need for back-up electricity production capacity to complement solar plants and wind turbines and is forecasting a trebling in earnings by 2025. It is already planning to build four modern open-cycle gas turbine (OCGT) plants, provided they obtain contracts in the capacity market auctions. For more visit:-

http://www.euronews.com/2017/06/15/drax-says-may-convert-coal-units-to-run-on-gas

Research Updates

EPSRC - new CCS, Bioenergy and Waste Management projects started after 1st January 2017

CCS projects

Grant reference number	Title	Start date	End date	Organisation	Value (£)
EP/R000131/1	Aerogel composites for carbon capture and thermal management in commercial buildings - Feasibility Study	28.05.17	27.11.18	Newcastle University	146,542
EP/P026435/1	CO2Chem Network: Establishing the UK as World Leaders in Carbon Dioxide Utilisation	18.06.17	17.06.19	University of Sheffield	253,037
EP/P032737/1	Corrosion Prediction in Residual CO2 Streams: Shifting the Paradigm	01.04.17	31.03.18	University of Leeds	60,478
EP/R000468/1	High Permeance Membranes for Rapid-Response Retro-fit Carbon Capture	01.08.17	31.07.19	University of Edinburgh	202,084
EP/R001308/1	Multi-stimuli Responsive Smart Hydrogels for Energy-Efficient CO2 capture	01.05.17	30.04.19	University of Nottingham	202,285
EP/P034594/1	Redefining power generation from carbonaceous fuels with carbonate looping combustion and gasification technologies	01.05.17	31.10.18	Cranfield University	157,213
EP/R000727/1	Renewable Hydrogen: Simultaneous Storage of Biorenewable Energy and Carbon Dioxide	01.08.17	31.01.19	Lancaster University	186,134
EP/P030548/1	SPIN-Lab	01.04.17	31.03.18	Imperial College London	1,907,995
EP/P026214/1	UK Carbon Capture and Storage Research Centre 2017 (UKCCSRC 2017)	01.04.17	31.03.22	University of Sheffield	6,233,759
				TOTAL	**£9,329,527**

BIOENERGY projects

Grant reference number	Title	Start date	End date	Organisation	Value (£)
EP/P022863/1	Application of microwaves on the production of liquid biofuels	01.09.17	28.02.19	Cranfield University	100,993

EP/R000298/1	Bio-CO2: Power Generation and Heat Recovery from Biomass with Advanced CO_2 Thermodynamic Power Cycles and Novel Heat Exchanger Designs	01.06.17	31.05.19	Brunel University London	198,383
EP/K036750/2	Clean Energy Utilisation from Biogas and Biomass Gasification	01.03.17	31.08.17 (?)	Queen Mary, University of London	235,826
EP/P030238/1	Enhancing the Methane Generation from Food Waste Anaerobic Digestion Mediated by Fluidic Oscillator Generated Microbubbles	20.02.17	19.02.18	University of Sheffield	80,887
EP/R000670/1	Microwave-assisted upgrading of fast pyrolysis bio-oil using structured zeolites on microwave-absorbing foam supports	01.09.17	28.02.19	University of Manchester	198,860
EP/P007821/1	Multiscale tuning of interfaces and surfaces for energy applications	01.01.17	31.12.20	University of St Andrews	2,075,702
EP/P034101/1	Novel intensified liquid-liquid contactors for mass transfer in sustainable energy generation.	01.06.17	31.12.18	UCL	197,725
EP/P03070X/1	Novel Production Process for Renewable Hydrogen from Animal and Human Waste	01.04.17	31.03.18	Coventry University	121,726
EP/R00076X/1	NWaste2H2- H_2 Production by Reforming Bio-methane with Nitrogen Rich Waste Streams	03.07.17	02.07.19	University of Leeds	202,491
EP/P032826/1	Rice straw to Biogas (R2B)	01.03.17	29.02.20	University of Southampton	276,754
EP/P030874/1	Rice straw to biogas (R2B) project	01.04.17	31.03.20	University of Manchester	180,806
EP/P024823/1	SUPERGEN Bioenergy Hub Extension	01.08.17	31.07.18	University of Manchester	756,074
EP/P016650/1	Sustainable excretable biofuels process design and optimisation	01.04.17	31.03.20	IC London	304,000
EP/P020836/1	Travel Grant Application: Dynamic Energy Planning: Global and National Resilience	01.03.17	28.02.18	University of Bath	9,684
EP/030688/1	Robust Decentralised Low Energy Faecal Sludge Dewatering leading to Sanitation, Clean Water and Sustainable Energy Resource	01.02.17	30.04.18	University of Strathclyde	42,182
EP/P03103X/1	Solar Oil	07.04.17	06.04.18	Cranfield University	40,313
EP/P018165/1	Understanding biomass value chains and the environment-food-	15.05.17	14.05.19	University of Bath	197,426

	energy-water nexus in Malaysia through whole-systems analysis and optimisation (BEFEW)				
					£5,219,832

WASTE MANAGEMENT projects

Grant reference number	Title	Start date	End date	Organisation	Value (£)
EP/N026519/1	Biologically Upcycling Metals	01.03.17	28.02.22	University of Edinburgh	1,020,945
EP/P016405/1	Novel Membrane Catalytic Reactor for Waste Polylactic Acid Recycling and Valorisation	01.04.17	31.03.20	University of Birmingham	740,016
EP/P008917/1	REBUILD - REgenerative BUILDings and products for a circular economy	01.02.17	31.01.20	University of Bradford	1,034,547
EP/P018513/1	Water - Energy - Nutrient Nexus in the Cities of the Future	15.05.17	14.05.19	University of Surrey	41,621
EP/P008771/1	Whole systems understanding of unavoidable food supply chain wastes for re-nutrition	01.01.17	31.12.18	University of York	822,615
					£3,659,744

Calendar of Fuel & Energy Research Meetings and Events

Date	Title	Location	Contact
12th September 2017	**"Carbon Capture and Storage, (CCS), Research Projects funded by the Research Councils and the UK Government" -Joint Seminar of the UKCCSRC with the FERF Carbon Capture and Storage Interest Group**	**The Edge, University of Sheffield, Sheffield**	**Prof. Jon Gibbins** **Chairman of the CRF Carbon Capture and Storage Division** **Tel : 0114-215-7234** **E-mail : j.gibbins@sheffield.ac.uk**
25th to 29th September 2017	Joint ICCS&T and ASCE Symposium	Beijing	For details contact:- http://iccstacse.cumtb.edu.cn/
Monday 2nd October 2017	**The 2017 Energy Science Lecture entitled, "The Integrated Energy Network ", to be presented by Dr Arshad Mansoor, Senior Vice President of R&D at the Electric Power Research Institute (EPRI), organised by the Biomass and Fossil Fuel Research Alliance, (BF2RA), with sponsorship from the**	**Prince Philip House, 3, Carlton House Terrace, London.**	**Mr. J.D.Gardner,** **BF2RA Company Secretary,** **Gardner Brown Ltd.,** **Calderwood House,** **7 Montpellier Parade,** **Cheltenham, GLOS , GL50 1UA.** **Tel : 01242-224886** **Fax : 01242-577116** **E-mail : john@gardnerbrown.co.uk**

	Fuel and Energy Research Forum, (FERF).		
2nd to 4th October 2017	Renewable Energy from Waste Conference	Fort Myers, Florida, USA	Website:- http://www.rewconference.com/
6th to 7th November 2017	5th International Conference on Coal Washing – 'Coal Washing: a sustainable approach towards greener environment'	India Habitat Centre Lodhi Road, New Delhi, India	CONFERENCE SECRETARIAT Dreamz Conference Management Pvt.Ltd 218 Ansal Majestic Tower, Vikas Puri, New Delhi – 110018, India Tel: +91 11 41586401, 402, Helpline / Whatsapp No - +91 9873089908 Email: cpsi.indiadelhi@gmail.com, info@dreamztravel.net Website: http://ice5e2017.cpsi.org.in
April 2018 Date to be announced	**FERF 2018 Annual Meeting and Environment Interest Group Seminar, "Environmental materials – Sorbents, Filters, Catalysts and Other Material".**	**Department of Chemical Engineering, Imperial College London.**	**Dr. David J.A.McCaffrey, Secretary of the Fuel & Energy Research Forum, Tel : 01242-236973. E-mail : mail@tferf.org Dr Bill Nimmo, Environment Interest Group Co-ordinator, University of Sheffield, Tel. 0114 215 7213. w.nimmo@sheffield.ac.uk**
To be advised	**"Carbon Dioxide Utilisation", Seminar of the FERF Advanced Power Generation and Gasification Interest Group**	**To be advised**	**Dr Robin Irons, Advanced Power Generation and Gasification Interest Group Co-ordinator, Tel 07765 896878. E-mail : robin.irons@uniper.energy**
3rd to 8th June 2018	9th International Freiberg Conference:- Closing the Carbon Cycle	Berlin, Germany	Website http://www.gasification-freiberg.de/en
Wednesday 5th to Friday 7th September 2018.	**12th ECCRIA Conference, The European Conference on Fuel and Energy Research and its Applications, (ECCRIA 12).**	**Cardiff University, Cardiff, Wales.**	**Dr. David J.A.McCaffrey 12th ECCRIA Conference Chairman Secretary of the Fuel & Energy Research Forum Tel : 01242-236973 E-mail : mail@tferf.org Dr Robert Berry 12th ECCRIA Conference Secretary Tel. 02058 331 9401 E-mail : r.j.berry@gre.ac.uk**