Biomass and Fossil Fuel Research Alliance (BF2RA)

2017 Targeted Call for Proposals

Closing Deadline for Outline Proposals - 1700hrs 17th February 2017

Summary

BF2RA (The Biomass and Fossil Fuel Research Alliance) operates a programme to support research into the clean and efficient use of biomass and fossil fuels, to build capacity in this area.

Proposals are invited for specific research relating to the following:

- Advanced Flame Monitoring as a Tool to improve Boiler Performance
- Handling and Transport of Compressed Wood Pellets
- Large Plant Asset Management
- Fate of Heavy Metals during Large Scale Combustion
- Materials Challenges

Details of these specific research topics are presented later in this document.

This is a two-stage proposal process. First outline proposals are invited and after evaluation, successful applicants will be invited to submit full proposals. Specific conditions will be applied to funded proposals and these can be found later in this call document.

Background

Several studies have concluded that fossil fuels may remain our most important fuel source for the next few decades. This is primarily for power generation, other conversion processes (such as the metallurgical industry) and general industrial application, both worldwide and within the UK. Renewable fuels, including biomass will also play an increasingly significant role in the medium to long term.

Fossil fuel is, and will probably remain, relatively cheap, and developing means of using it cleanly, either directly, in conjunction with biomass or as a source of other vectors, should be a priority. There are many facets of fossil fuel and biomass R&D which still need to be undertaken, including underpinning science to support the development of technologies which could allow the continued use of fossil fuels and particularly coal in an environmentally acceptable manner.

A further critical requirement is to provide a new generation of engineers, scientists and technologists to build capacity in fossil fuel and biomass related core skills in the UK.

BF2RA's Research Portfolio

BF2RA comprises six 'world-class' power generation, equipment supplier, research sector and fuel user organisations and has to date established a portfolio of 24 R&D projects recruited during the period 2010-2016.

The annex to this document contains summary details of the BF2RA current project portfolio together with information on completed projects.

Funding available

BF2RA will provide funding of typically £25-40k per successful application to support PhD/EngD research or in well justified cases, RA based projects. It is envisaged that the University will provide the matching funding from DTC, Case or other funding mechanisms.

Research outlines against which proposals are invited

1. Advanced Flame Monitoring for Improving the Performance of a $49MW_{th}$ Coal-fired Travelling Grate Boiler Plant

British Sugar's Cantley Factory operates a $49MW_{th}$ coal fired chain grate to produce for its CHP plant and other similar plants globally. The combustion efficiency of the grate/furnace is significantly affected by coal quality and origin. However there is no method available for online monitoring and quantifying of the performance of the combustion process within the furnace both on and above the grate. The current practice of determining the combustion efficiency is partly through the determination of the unburnt carbon in ash contents. The whole process takes up to nine hours, resulting in a significant delay in feedback control of the system. It is therefore desirable to develop an on line techniques that can monitor thermal and efficiency performance within the furnace to enable continuous and predictive optimisation including advising the operators on actions to take. Examples of techniques include sophisticated flame monitoring and analysis.

The technology and techniques developed will be applicable to other solid fuel combustion systems, such as biomass.

Universities are invited to submit proposals for BF2RA funding for a PhD project, starting in September 2017.

British Sugar will provide the Industrial Supervisor and trial opportunities.

2. Flow Modelling of Compressed Wood Pellets discharging from Large Scale Storage with Multiple Outlets

A model (either physical or computational) to track and simulate the flow of compressed wood pellets exiting a large scale storage facility with multiple outlets would have many advantages for fuel tracking (accounting for ROC's, section of fuels based on CV, fines and type) and safety factors when removal of a "hot spot" is required.

- The proposed scheme would be for free falling compressed wood pellets entering a single point at the top of the storage facility, with the ability to discharge from the base via multiple out lets (i.e. 2 x rows of 8) at varying rates of 200-3000 t/hr.
- Simplistic models work on a "First In, First Out" method and assume basic layering of materials, but this is clearly not the case even with a single outlet discharge and therefore multiple combinations are possible as the number of outlets increases.
- Modelling of fines segregation.
- Understanding flow of pellets within the storage facility would aid in the movement and discharge of any hot sports of material.
- The multiple outlet discharge facility is utilised for safe and control discharge of hot spots identified within the storage facility via temperature strings located within.
- Correlation of temperature detected on a thermocouple string to a maximum prediction of temperature a distance from the thermocouple would aid in true maximum hot spot prediction and possible location.
- This work could be linked to off gassing from the store to aid in product quality from self-heating break down.

3. Investigation into the Disintegration of the Compressed Wood Pellets leading to the Release of Dust and Fines

The intention is to investigate the effect of pellet breakage from other sources, including:

- Moisture migration within the pellet from possible case hardening and effect on hoop stress.
- Moisture migration within the pellet from different sized particles with different moisture contents, and effect on hoop stress.
- The inclusion of different species / foreign bodies within a single pellet.
- The prevention of moisture migration within the pellet by effective lignin mobilisation, forming water-tight boundaries.
- Drying the pellet after manufacture, caused by low humidity air from cooling fans or injection of dry gas.
- Wetting the pellet after manufacture, caused by high humidity air from cooling fans.
- Poor lignin mobilisation in the pelletiser, as may be evidenced by a change in the glass transition temperature of the product, or other such property.
- Characterising the breakage of pellets while under a high hydrostatic pressure, when gently shaking or flowing (i.e. when in a ship's hold or flowing through a silo). Relationship to be determined with the length of pellet.
- The effect of thermal cycling and high temperatures in ventilated, and un-ventilated spaces.
- Other relevant factors that the researcher may discover.

The effectiveness of the industry's standard pellet test for durability should be evaluated for each of the above scenarios.

4. The Mapping and Fate of Heavy Metals (HM) during Large Scale Combustion

HM are components of coal and biomass fuels. Their fate and transformation products during large scale combustion are a function of boiler design, temperature regimes, residence times, etc. Most of the HM are solid compounds after the boiler, except for Hg and Se, and during the combustion process they tend to be concentrated (enriched) on finer particles. However there could be a significant difference between what we call enrichment factors (increased concentration of HM as w%), for biomass applications compared with that of coal. For coal applications some HM mapping of fuel to stack has been undertaken although results have been generally inconclusive. The normal way to control the HM is by way of control of the particulate emissions as reflected by LCP-BREF for the EU. However during biomass firing and co-firing applications there is the potential of high HM emissions.

More information is needed in this area with regard to mapping, namely:-

- Mass balance from the fuel to the bottom/boiler, the fly ash and any downstream particulate collector.
- For different type of boilers, specifically for FB boilers and specifically for CFB boiler as these are popular for large scale biomass applications.
- Using biomass fuel, virgin as the baseline but also virgin biomass with co-firing with waste like demolition wood of different qualities
- Mapping includes
    - Fuel composition, not only the HM but also other fuel components
    - The boiler ash composition
    - The fly ash composition upstream the installed air quality control equipment
    - To limit the scope, the focus should be on HM including Hg, but other parameters like acid components and dioxins/furans will be of added value.
    - With the focus on HM and to be able to find the criteria for the particulate collection device, controlling the HM emissions to stack, the mapping of HM vs the particle size is a key parameter. The enrichment factors, see above, for a fabric filter, will be an alternative, and in reality used in predicting the performance.

- All of the above should be supported/complemented/concluded with a theory for how HM find their way from the fuel to the stack.

5. Large Plant Asset Management

UK coal-fired power plants operate under widely different conditions from those for which they were designed, e.g. two-shifting and load following (renewables balancing) rather than base-load operation. Consequently, the pressure parts are subjected to far harsher temperature and pressure cycling conditions than had been anticipated at the time of their design, which can result in failure. The plants have also had their operating lives extended significantly beyond their design lifetimes and they fire fuels that are more challenging than their design fuels. Failure of pressure parts in service can introduce hazards for personnel and plant and also results in significant repair and lost generation costs during the unscheduled outages required for repairs. Very large cost savings would result from several mechanisms, including:

- Ability to predict pressure part failures and allow the repair/replacement of affected parts during planned outages.
- Maximise load ramp rates and minimise start-up times.
- Maximise cycle efficiency with minimal detrimental impact on plant operating life.

Proposals are invited to develop tools that would address one or more of the identified cost saving mechanisms, for example:

- A model that can correlate pressure part failure with historical plant operating data. The model could address furnace tube and/or superheater/reheater tube failures and should be suitable for application on different power plants without requiring significant modification.
- Coupling plant control system with performance and reliability models to permit techno-economic assessment of the benefits resulting from increased ramp rates and increased cycle efficiency versus costs incurred due to possible reduced plant reliability/increased maintenance requirements.

Note that the viability of the projects is dependent on the availability of historical operating data from a suitable power plant.

6. Materials Challenges

Outline proposals are invited on materials challenges including those that focus on fossil fuel fired plant including advanced designs, operational reliability, the impact of increased cyclic operation, non-destructive techniques for assessing material condition and the use of alternative fuels such as biomass

The Call Process and Schedule

- Call Issued – before 6/01/2017
- Deadline for submission of Outline Proposals – 1700hrs GMT 17/02/2017
- BF2RA Panel review of Outline Proposals – week beginning Monday 13/03/2017
- Full proposals invited – week beginning Monday 20/03/2017
- Deadline for submission of Full proposals – 1700hrs BST 13/04/2017
- BF2RA Panel review of Full Proposals – week beginning Monday 1/05/2017
- Advise outcomes, week beginning Monday 15/05/2017 and initiate contracting process in preparation for October 2017 project starts.

Outline Proposals should be submitted electronically to technical@bf2ra.org by the deadline indicated above.

Outline Proposals must not exceed two pages (minimum font size 10). Further they should include full contact details (email address and telephone number) of the lead proposer/institution. Outline proposals should reflect accurately the research specification and detail the intended methodology. There is no requirement for financial breakdown at this stage except for a statement confirming the availability of top-up funding should BF2RA offer a grant.

Proposals will be assessed against the following primary criteria (in no particular order of priority):

- Understanding of BF2RA's outline specification
- Quality of the research proposed
- Relevant skills and expertise
- Demonstration that effective management arrangements and planning is in place
- Industrial relevance and potential for impact
- Cost and value for money

Special Conditions

BF2RA will manage the monitoring of the selected projects and will provide an Industrial Supervisor for each project. The Industrial Supervisor will be responsible for the monitoring of the project, working closely with the University Project Manager. This will include the attendance by the Industrial Supervisor at six-monthly project progress meetings, which may also be attended by members of the BF2RA and/or their representatives, and the review of the six-monthly progress reports. Six-monthly progress reports and a final report will be provided by the University Project Manager to BF2RA. A duty of the Industrial Supervisor will be to approve, (or otherwise), these Six-monthly and Final Reports through an agreed procedure prior to making stage payments to the University during the course of the project.

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Annex – BF2RA's Project Portfolio

Dynamic Modelling and Simulation of Supercritical Coal-fired Power Plant with CO_2 Capture Ability (Completed). The aim of this project was to develop a dynamic model for the whole supercritical coal-fired power plant by modelling the water/steam cycle and the air/flue gas cycle of a typical supercritical coal-fired power plant. This dynamic model for supercritical coal-fired power plant was linked with the dynamic model for CO_2 post-combustion capture plant (being developed by another PhD project). This enabled determination of a key design and operation issue, namely, whether such a supercritical plant with CO_2 capture ability can satisfy the UK grid requirement.

Intelligent Flame Detection Incorporating Burner Condition Monitoring and On-Line Fuel Tracking (Completed). This project aimed to develop a cutting edge flame monitoring technology that can also indicate the condition of the burner and track the type of coal and/or biomass fuels. This has been achieved by developing a technology for flame stability measurement, burner condition monitoring and on-line fuel tracking through digital imaging and flame signature analysis; evaluating the technology under a range of biomass firing, coal/biomass co-firing, and oxy-fuel fired conditions on a combustion test facility and on a full scale multi-burner furnace; and making recommendations for improvements of existing furnaces through the use of the new technology

Impact of Biomass Torrefaction on combustion behaviour in co-firing (Completed). The principal aims of this project were to investigate a number of the key fundamental issues associated with the development of torrefaction technology for a wide range of biomass materials that will help to promote the more widespread use of torrefied materials especially in the UK. An electrical heated horizontal tube furnace was commissioned for the generation of torrefied fuel. Following drying of the raw biomass, samples of each fuel were then subjected to three different torrefaction temperatures (240, 260 and 280 ^{o}C) and at two different residence times (30 and 60 minutes). The fuels were then characterised using TGA, SEM and C13 NMR techniques. A drop tube furnace (DTF) has been used to generate chars from raw biomass and torrefied fuel samples under a number of conditions with varying parameters such as particle size, residence time and furnace temperature. The combustion reactivity's of the DTF chars has been compared to those generated from TGA experiments. The fundamental results in this study have provided an insight into the combustion properties of torrefied biomass fuels, the kinetic data can be used in CFD modelling to optimise the design of burners for combustion of torrefied fuel.

Avoiding Sintering of Coal-Fired Shallow Fluidised Beds (Completed). The project focused on the investigations of the main causes of bed sintering/defluidization during 'lump' coal combustion in shallow fluidized bed combustors. The project also investigated the effect of co-firing biomass on the bed materials' sintering and fluidization. The 'alkali getter' technique was explored to alleviate/avoid bed sintering/defluidization during co-firing biomass with lump coal in shallow fluidized beds. A range of laboratory based experiments and analysis of materials obtained from an industrial fluidised bed have been carried out. The former has looked at the impact of coal on agglomeration and the latter has focused on investigation of agglomerated material removed from an industrial fluidised bed following shutdown

Milling and Conveyance of Biomass (Completed). The aim of the project WAS twofold, to investigate milling behaviour of a range of biomass materials and to investigate how these milled biomasses impact pipe wear. This was achieved by bench scale milling, analysis of the milled products and design and use of a test rig to rank milled products in a test pipeline. Early work focused on identifying the matrix of different biomass tested on different mills drawn from literature, identifying process variables for specific mill types and the comparison of particle size analysis methods for biomass size fractions. Subsequently a review of the options for characterisation methods for the grinding of biomasses, wear on hammers in mill and hardness of metal vs. Biomass was investigated.

A New Classification System for Biomass and Waste Materials for use in Combustion (Completed). The overall aim of this project was to develop a classification system for non-coal materials, analogous to those which have been widely applied in the utilisation of coals. This involved a comprehensive characterisation of a range of potential biomass fuels in terms of their elemental and chemical analyses along with a study of their structural composition, namely lignin, cellulose, hemicellulose, lipids and other aliphatic polymers such as resins. Further it included an investigation of de-volatilisation and char burn-out behaviour in order to develop the new classification system as a predictive tool for combustion behaviour and its efficacy when applied to blends with coals.

Modelling chemical and micro-structural evolution across dissimilar interfaces in power plant alloys (Completed). This project addressed the Materials Development priority theme of the BF2RA call in that it was directly relevant to the performance, in-service, of fusion welded joints between dissimilar alloys (eg steels and nickel alloys or different steel grades). It was also pertinent to the development of advanced plant components which require protective coatings by weld overlay or thermal spraying for the more aggressive operating environments of biomass combustion.

Development of a Novel Feeding System for Pressurised Combustion/Gasification Processes (Completed). The overall objective of this project was to develop a novel, reliable and efficient system for continuous feeding of solid fuels (e.g. biomass, coal and/or waste) to high-pressure environments. This type of feeding system will enhance the commercial viability of high-pressure gasifiers and combustors operating on solid fuels by increasing the efficiency of the plant as a whole. A new feed system, named Hydraulic Lock Hopper (HLH), has been developed to primarily counter issues with efficiency. The HLH uses water as an incompressible fluid to minimise the energy required for feeding. The HLH has been operated at pressures as high as 25 barg and has successfully demonstrated the feeding of commercially available wood pellets, torrefied spruce pellets and ground anthracite coal grains. The HLH has demonstrated energy savings of approximately 80% at 25 barg for all fuels compared to a conventional single lock hopper.

Low Temperature Ignition of Biomass (Completed): This one year post-doctoral research project commenced in late 2012 and has now been completed. The overall aim of the research was to characterise and measure the ignition properties and temperatures for a range of relevant biomass fuels. The influence of (i) moisture (ii) particle size (iii) oil content (iv) oxygen concentration in the ambient atmosphere, on ignition and reaction was studied. The data has been used to categorize the biomass in terms of its ignition risk in both storage, milling, and transport in entrained flows.

Development of Novel Coatings to Reduce Fireside Corrosion in Biomass-fired Power Plants (Completed): The overall aim of this research is to use a novel, rapid coating development methodology to identify coating compositions that will resist the fireside corrosion environments found on superheater and reheater tubes in combustion plants firing a high proportion of biomass fuels. Specific objectives include: use the "combinatorial alloy development" methodology to generate a wide range of potential coating compositions, to screen these using carefully targeted fireside corrosion exposures to identify the most resistant coating compositions, apply the most promising coating compositions onto heat exchanger tube materials to investigate the thermal stability of the coating/tube combinations and to assess alternative methods of applying the most promising coating compositions onto heat exchanger tubes.
Thermal stability tests of deposits have been carried out to identify a suitable screening deposit composition, which can be used in the fireside corrosion tests. Coatings deposition has been investigated using a multiple target magnetron sputtering coater and oxidation tests of the coatings have been undertaken. This research was completed in early 2016.

Integrity of Coated Ferritic Alloys under High Temperature Creep and Fatigue (Completed): The overall aim of this research is to investigate the integrity of coated ferritic alloy samples subjected to high temperature exposure and steady/cyclic mechanical loadings. This will result in gaining a better understanding of presently developed coatings and the associated key failure mechanisms, ranking of the potential coatings based on test results and provision of a generic understanding of factors limiting coating service life. Characterising of the substrate and coating material to allow a greater understanding of the physical and chemical properties has been undertaken. A mechanical testing programme has also commenced with creep tests of the uncoated substrate steel. A number of uniaxial and notched bar tests, at a variety of stresses, have been completed for the uncoated material and interrupted tests are being planned for the future. Work has also started on examining the failed specimens to understand the evolution of microstructure during creep and to determine the failure mechanisms.

Biomass Exacerbated Cyclic Oxidation of Steels in Steam: The overall aim of this research is the development of a model for steam side oxidation growth and spallation both prior to and after the initial spallation event based on laboratory observations in simulated cyclic steam oxidation experiments. This will build on current research at the University of Birmingham investigating/modelling steam oxidation and spallation of austenitic stainless steels.

Biomass Co-firing to Improve the Burn-out of Unreactive Coals in Pulverised Fuel Combustion: The overall aim of this research is to determine for a selection of unreactive bituminous coals the extent to which relatively small emissions of biomass can (i) increase volatile yields and so reducing ignition temperatures and (ii) improve char burn-out.

Modelling of Biomass Milling: This study uses data generated by the Milling and Conveyance of Biomass project (described earlier) as a base to investigate and validate modelling approaches. The overall aim of the research is to identify the most pragmatic modelling approaches for use in the energy industry and so understand the implications of milling to biomass choices. The output from this research will be a validated model and an understanding of the fundamental science behind biomass milling, with a clear appreciation of the advantages and limitations of the modelling methods.

Modelling Fireside Corrosion of Superheaters and Reheaters following Combustion of Coal and Biomass: The aim of this research is to develop a suite of interconnected models to predict the degree of fireside corrosion damage experienced by superheaters/reheaters in coal- and biomass-fired boilers. This project was recruited via the 2014 BF2RA Call and research commenced early in late 2015.

Assessment of Spontaneous Combustion Risk: The aims of this research are to advance the understanding, diagnostic and predictive capability for detecting self-heating in biomass piles, and for prediction of risk from a knowledge of the biomass type and properties. This project was recruited via the 2014 BF2RA Call and research commenced in early 2015.

Slagging and Fouling Prediction using an Advanced Ash Fusion Test: This research aims to develop a novel method to predict the slagging and fouling potential of different types of coal, biomass and blends using an advanced ash fusion test. At present the standard test is subjective and relies on manual observations of ash behaviour.

Interpretation of Small Specimen Creep Test and Recommendations on Standardisation of Impression Creep Test Method: The overall aim of this research is to develop a framework for the implementation of the results of small specimen creep testing for assisting in long-term power plant material performance assessment and component life management.

The Performance of High Chromium Creep Strength Enhanced Ferritic Steels: The overall aim of this research is to understand the effect of processing and composition on the long-term performance under service conditions of 11-12 wt.% CSEF steels. Recruited from BF2RA's 2015 Call and research commenced in October 2016.

Additives to Mitigate against Slagging and Fouling in Biomass Combustion: The aim of this research is to understand, through experiment and modelling, the impact of pfa as an additive in the combustion of biomass in both suspended and fluid bed firing and using the mechanistic insight gained to make recommendations on industrial best practice for minimising slagging and fouling in biomass combustion. Recruited from BF2RA's 2015 Cal and research commenced October 2015.

Investigation of Potential of Co-milling Biomass PFA with Cal to reduce NO_x Emissions: To understand the impact of biomass PFA or FBA as an additive in the reduction of NOx emissions from large-scale combustion of coal. Recruited from BF2RA's 2015 Cal and research commenced late 2015.

Rapid Fuel Evaluation using Image Analysis: The aim of this research is to develop an image analysis method the can rapidly characterise fuel to predict boiler performance. Recruited from BF2RA's 2015 Cal and research commenced October 2015.

Advanced Flame Monitoring and Emission Prediction through Digital Imaging and Spectrometry: The proposed project aims to develop an instrumentation system for monitoring burner flames and predicting emissions on a multi-burner heat recovery boiler using digital imaging and spectrometric techniques. Research commenced late 2015.