Biomass and Fossil Fuel Research Alliance (BF2RA)

2016 Targeted Call for Proposals

Closing Deadline for Outline Proposals - 1700hrs 19th February 2016

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.

Bids are invited for proposals for specific research relating to the following:

- Energy Storage
- Improved Performance of Large Plant
- Asset Management including Intelligent Control

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 50 years. 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, which comprises six 'world-class' power generation, equipment supplier and coal utilisation organisations has to date established a portfolio of 23 R&D projects recruited during the period 2010-2015.

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 £30-40k per successful application to support typically PhD/EngD 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. Integration of Energy Storage in Thermal Power Plant

Non-dispatchable renewable power technologies such as wind and PV are already increasing their penetration of the UK energy mix and this is set to increase significantly in the future. The impact on existing thermal power plant is that they have to operate more flexibly, with increased part load operation, faster ramp rates and even increased start-up/shut-downs.

An alternative approach to component/system design change to increase flexibility is to incorporate energy storage. This would allow the power plant to operate at closer to its design point, maintaining optimum thermodynamic efficiency and allowing longer power plant component lifetime.

This R&D project therefore aims to investigate the potential for energy storage in thermal power plant, to allow near optimal power (base load) plant operation whilst meeting the future flexibility needs of the UK grid. The focus should be power plant lifetime extension, either for conventional sub-critical or combined cycle gas turbine power plant. The type of energy storage (i.e. whether variants of thermal or electrical storage) is open to the applicant to define, but the choice should be fully justified. The business case for energy storage will of course be a trade-off between the additional cost of the energy storage system vs the extended life-time and enhanced economics of the existing power plant. Consideration should also be given to the case where the trermal plant is providing renewable energy by firing biomass and the associated renewable subsidies/ CO_2 cost savings factored into the economics. The additional ancillary services that certain types of energy storage can offer, could also be a feature of the business case.

The specific objectives of the proposed R&D are to;

- Define cycle configurations to integrate energy storage in to existing coal, biomass or gas power plant. This could be extended to incorporate renewable energy such as wind or solar in to the power plant cycle.

- Demonstrate achievement of current and future UK grid code compliance whilst operating the thermal power plant at near to base load operation through the use of energy storage
- Define value proposition/business case for the proposed energy storage which could include power price arbitrage/ peak power boosting and grid ancillary services

Industrial partners in the project will be able to provide information on currently operating conventional sub-critical or combined cycle gas turbine power plant to support the research.

2. Improved Performance for the Reliability and Flexibility of Large Plant

This R&D project aims to investigate the effects of combustion behaviour on open cycle GT and CCGT Gas Turbine Operation and to propose potential improvements that can reduce through life cost of ownership.

Open cycle GT and CCGT plant operators face various operational challenges due to natural gas (fuel) price and load demand. The use of GT's in power generation is generally preferred to conventional thermal coal/biomass generation plants because they can achieve faster ramp up/down rates. This means that both open cycle GTs and CCGT's are more susceptible to integrity issues due to frequent cycling, with subsequent impact on plant reliability and increased maintenance frequency, which in turn translates to higher operational costs.

In gas turbines, combustion behaviour is of prime importance especially in cycling situations, where it is known that at lower loads there is a tendency for combustion instabilities, which can often translate into higher CO emissions due to the Dry Low NOx (DLN) technology used. In addition, this can increase thermo-acoustically induced vibrations in the combustor region, reduce flue gas temperature and plant efficiency. All these have an impact on the materials and component life of the associated hot gas path components (i.e. combustor and transition pieces).

Furthermore, GT plant operation is often dependent on changes in ambient conditions, fuel quality and is also by the introduction of OEM designed plant upgrade packages.

The objective of the proposed R&D is to;

- Assess the impact of a varied fuel diet such as natural gas, LNG and for instance methane produced from bio-gasification, on GT performance at full load range (i.e. low to high loads) whilst meeting the required IED NOx and CO levels.
- Investigate and propose pragmatic solutions/options that can be used to improve the efficiency/stability of the combustion process. This may for example consider options such as improvements to combustion dynamics, use of advanced/novel instrumentation systems within the combustion chamber to improve our understanding etc.

Improving the combustion performance/stability will ultimately benefit the integrity of downstream hot gas path components and also reduce subsequent through life operation and maintenance costs.

Industrial partners in the project will be able to provide information on currently operating CCGT units to support the research.

Industrial partners will benefit from greater understanding of the key factors that affect combustion performance in industrial GT's, which will therefore, for example, enable more cost-effective decisions on plant operation and/or OEM plant upgrades to be made.

3. Large Power Plant Asset Management including Intelligent Control

BF2RA offers a general invitation to submit outline proposals relating to large power plant asset management including intelligent control.

The Call Process and Schedule

- Call Issued – 8/01/2016 at the latest
- Deadline for submission of Outline Proposals – 1700hrs GMT 19/02/2016
- BF2RA Panel review of Outline Proposals – week beginning Monday 7/03/2016
- Full proposals invited – week beginning Monday 14/03/2016
- Deadline for submission of Full proposals – 1700hrs BST 15/04/2016
- BF2RA Panel review of Full Proposals – week beginning Monday 25/04/2016
- Advise outcomes, week beginning Monday 9/05/2016 and initiate contracting process in preparation for October 2016 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) and 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.

Peter Sage, BF2RA Technical Officer.
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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: 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 will complete in early 2016.

Integrity of Coated Ferritic Alloys under High Temperature Creep and Fatigue: 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 scheduled to start early 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.