

# Biomass and Fossil Fuel Research Alliance (BF2RA)

## 2018 Targeted Call for Proposals

**Revised Deadline for Proposals - 1700hrs GMT 28<sup>th</sup>  
March 2018**

### 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:

- Condition Based Monitoring/Asset Management and Prediction Tools
- Plant Flexibility

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

**Please note that BF2RA has now moved to single stage project recruitment resulting in a quicker process as described later.** Specific conditions will be applied to funded proposals and these can also be found later in this call document.

### Background

Globally fossil fuels will 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. In the UK fossil fuels will remain an important fuel source until the mid-21<sup>st</sup> century although coal use for power generation will essentially disappear within the next few years.

There are many facets of fossil fuel and biomass R&D which still need to be undertaken, including managing large scale assets and improving operational flexibility. This will enable the residual use of fossil fuel and especially coal to be optimised.

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 five 'world-class' power generation, equipment supplier, research sector and fuel user organisations and has to date established a portfolio of 27 R&D projects recruited during the period 2010-2017.

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, Research Councils or other funding sources.

## **Research outlines against which proposals are invited**

### **Research Priority 1: Condition-Based Monitoring/Asset Management & Prediction Tools**

Coal and biomass-fired plants now 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, critical components and systems are subjected to thermal cycling conditions not anticipated at the time of their design leading to failure and unplanned operational cost. Many plants are also operating outside of the original design life and fire fuels that are challenging (world-sourced low quality coals and various biomass materials) in terms of plant operation and optimisation.

Operational examples include, the failure of pressure parts and process equipment in-service introduces hazards for personnel and plant resulting in significant repair and lost generation costs. Slagging and fouling of heat transfer surfaces adversely affects boiler operations and plant cycle efficiency.

Significant cost savings can be realised through condition-based monitoring and prediction tools to enable asset optimisation. Such applications could include:-

- Improving the capability to predict pressure part failures and the rate of degradation thereby allowing the repair/replacement of affected parts during planned outages
- Optimising the scope of invasive statutory outage inspections
- Improved understanding of operational risks and with subsequent feedback to station operators
- Innovative data analytics to improve the utilisation of data currently routinely captured either during an outage overhaul inspection or as part of normal operational monitoring
- Maximising load ramp rates and minimise start-up times
- Monitoring and life prediction of critical welds operating at high temperature and pressure

- Maximising cycle efficiency with minimal detrimental impact on plant operating life
- Development of novel fuel quality assessment tools e.g. slagging and fouling prediction indices/tools for aggressive coals and fuel blends

Proposals are invited to develop monitoring and prediction tools that would target one or more of the above development topics and which could be effectively used by an asset owner.

## **Research Priority 2: Plant Flexibility**

Due to introduction of renewable energy sources for power production over recent years there has been a fundamental change in electricity systems and markets.

More variable power production increases the flexibility requirements placed on the overall power system, both on the supply and demand sides and it is often claimed that existing conventional power plants, especially large coal-fired power plants, cannot cope with impact of weather-dependent generation of wind and solar power. Flexible operation (rather than base-load generation) is shaping modern power systems and increasing the flexibility of existing power plants is necessary to enable the integration of renewable sources into the system.

Proposals are invited that address the topic of improved power plant flexibility through rapid (higher) ramp rates, lower minimum loads (minimum stable generation), and shorter start-up times. Examples of improved flexibility with acceptable impact on component life, efficiency and emissions could include;

- Boiler Plant
  - Firing Systems e.g. no. of mills in operation to permit lower load / greater load range; installation of indirect firing systems
  - Pressure Parts e.g. pressure part flexibility / material selection / replacement thinner section of key components (design and manufacturing improvements) for faster load changes
  - Boiler box-up procedures for effective plant preservation during off-load periods
- Turbine Plant and Water / Steam Systems
  - Turbine bypass systems
  - Load following using sliding pressure operations
  - Rapid response for frequency control
  - Energy storage options
- Balance of Power Plant
  - AQCS emissions control plant (SCR / ESP / FGD) / gas path system upgrade
  - Auxiliary plant e.g. use of flexible drives
  - Optimisation of process system and equipment operation, performance and reliability
- Control Systems
  - Optimised boiler / turbine control & monitoring systems
  - Plant control upgrade with self-learning predictive systems

*Both Research Priorities strongly encourage the use of digital technology as a means of enabling improvements in the integrity management and operational performance of power generating assets.*

## **The Call Process and Schedule**

- Call Issued – by 17/11/2017
- Deadline for submission of Proposals – 1700hrs GMT 28/03/2018
- BF2RA Panel review Proposals – week beginning Monday 16/04/2018
- Advise outcomes, week beginning Monday 23/04/2018 and initiate student selection and contracting process in preparation for autumn 2018 project starts.

Proposals should be submitted electronically to [technical@bf2ra.org](mailto:technical@bf2ra.org) by the deadline indicated above.

Proposals must not exceed three pages (minimum font size 10). Further they should include full contact details (email address and telephone number) of the lead proposer/institution. Proposals should reflect accurately the research specification and detail the intended methodology. Proposals should state the funding requested and the full cost of the research together with a summary cost breakdown. Proposals should also confirm 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 are in place
- Industrial relevance, potential for impact and how benefits can be realised e.g. by deployment of models, etc. generated by the research
- 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 and the BF2RA Technical Officer. 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.  
e-mail: [technical@bf2ra.org](mailto:technical@bf2ra.org)

## Annex – BF2RA’s Project Portfolio

**Dynamic Modelling and Simulation of Supercritical Coal-fired Power Plant with CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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 °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 (Completed):** 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 (Completed):** 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 call for proposals and research commenced October 2015.

**Investigation of Potential of Co-milling Biomass PFA with Cal to reduce NO<sub>x</sub> Emissions:** To understand the impact of biomass PFA or FBA as an additive in the reduction of NO<sub>x</sub> 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 that can rapidly characterise fuel to predict boiler performance. Recruited from BF2RA's 2015 call for proposals and research commenced October 2015.

**Advanced Flame Monitoring and Emission Prediction through Digital Imaging and Spectrometry:** This 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.



**S-CO<sub>2</sub> for Efficient Power Generation with Energy Storage:** This research is evaluating the opportunity for new advanced power generation concepts and performance improvements using alternative fluid cycles (supercritical CO<sub>2</sub> (S-CO<sub>2</sub>), molten salts, etc.) for applications in combination with heat storage. The development of these new cycles requires solutions to the coupled challenges of fundamental technology development and systems engineering. The research will address the application and integration of these cycles for a variety of high-temperature heat sources to increase efficiency and the reduction of plant cycling, thus improving the life and reliability of existing power generation assets. Research commenced in October 2017

**Prediction of the Synergistic Effects of Degradation and Segregation in Handling and Storage of Wood Pellets for Power Generation:** This research aims to produce an holistic model to predict both segregation and degradation through a complete handling and storage chain from port to mill, including belt conveyors, large and small silos, flow into and out of rail wagons and pneumatic conveyors. This is intended to allow the prediction of fines and dust as the operational conditions progress with time (especially storage inventory). Using this, the operator will be able to explore methods to mitigate the difficulties, both in terms of operational philosophy and technical optimisation of the plant. This research was recruited from the 2017 targeted call for proposals and is scheduled to start in December 2017.

**Formation of Corrosive Compounds from Biomass/Waste Combustion:** The overall aim of this research is to assess the formation and impact of corrosive compounds from alternative solid fuel (e.g. biomass and waste) combustion and to compare with corrosive compounds arising from coal combustion. A mix of practical and modelling work will be undertaken. This research was recruited from the 2017 targeted call for proposals and is scheduled to start in early 2018.

**A Suite of On-line Combustion Evaluation Tools for Boiler Efficiency Improvement:** This research project will develop and test a set of on-line diagnostic tools that will improve operation management of a travelling grate stoker fired boiler. Three different (but complementary approaches will be used, namely, an empirical image analysis system, the development of a self-calibrating real time dielectric monitoring system and the development of a computational model for the travelling grate furnace, simulating solid fuel combustion. This research was recruited from the 2017 targeted call for proposals and research commenced in October 2017+