LBNet Proof of Concept (POC) Projects

Projects funded since 2014

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LBNet is a BBSRC-funded Network in Industrial Biotechnology and Bioenergy

Title: Maximizing the Real Value of Lignin (MaRVeL)	
Lead Applicant: Tim Bugg, University of Warwick	**Other Applicants:** Jason Hallett, Imperial College London; Samuel David Jackson, University of Glasgow; Nicholas Westwood, University of St Andrews; Sharif Zein, University of Hull

Public Summary

Lignin is an aromatic polymer that occurs as 15-30% of plant biomass, and is currently a low-value by-product of cellulosic bioethanol manufacture and pulp/paper manufacture, hence there is interest in converting lignin into renewable chemicals and bio-based materials. One of the main problems in the field is that there are many different methods for generation/preparation of lignin, and each of the resulting lignins is structurally different, and behaves differently when processed via biocatalysis or chemocatalysis. The aim of this proof of concept project is to bring together different researchers with experience of lignin preparation, characterisation, and valorisation, to prepare a set of lignins from different methods, and to process them via several different state-of-the-art methods. The results should establish whether there are particularly good (or bad) combinations of lignin preparation methods & lignin valorisation methods. This information will be extremely useful to guide the lignin valorisation community in their choice of lignin substrate. The results will also be used to guide the combination of lignin valorisation with 2nd generation biofuel production, which will add value to the lignin by-product, and help to realise the long term aim of a cellulosic biorefinery, producing fuels and chemicals from plant biomass. The project will also establish links to the UK biofuel industry (Vivergo) and bio-based plastics industry (Biome Bioplastics), and link with biorefinery research in Chile.

Public Project Outcome

Valorisation of lignin, the aromatic heteropolymer found in plant lignocellulose, is one of the major unsolved problems in developing the biorefinery concept for production of fuels and chemicals from plant biomass. One significant challenge in lignin valorisation is that there are many different methods for preparation of lignin from biomass, each of which has different physical properties, chemical structure and reactivity.

In order to address this problem, a set of eight different lignin preparations were prepared by research groups around the UK and in Chile, using a range of lignin isolation methods. The preparations were characterised by 2-D NMR spectroscopy, revealing in detail their molecular structures. The different preparations were tested against five state-of-the-art lignin valorisation methods: two chemical valorisation methods, and three biological methods (1 microbial fermentation, two bacterial lignin-oxidising enzymes). The results have shown quite variable products and product yields, confirming that lignin valorisation is highly dependent on the method used for lignin isolation. These results will be disseminated via a research publication, and disseminated to industrial biotechnology partners interested in lignin valorisation.

Title: Arabinoxylan co--production from sugarcane bagasse in integrated biorefineries (ACSIB)	
Lead applicant: Grant Campbell, University of Huddersfield	**Other Applicants:** Julian Cooper, AB Sugar; James Flint, University of Lincoln; Jon McKechnie, University of Nottingham; Gavin Thomas, University of York; Nicholas Westwood, University of St Andrews

Public Summary

Arabinoxylans are potentially a healthy soluble fibre food ingredient with prebiotic activity. Meanwhile, sugarcane bagasse is a low value by-product of sugar and bioethanol production, from which arabinoxylans could be extracted to produce a high value revenue stream and a new class of functional food ingredients. One of the processes for producing arabinoxylans uses ethanol for precipitation; co--production of AX with bioethanol production therefore gives scope for integrated processing and economic production of AX. The current proposal will establish the scientific and process engineering bases for commercially viable production of arabinoxylan in the context of an integrated biorefinery, for use as a novel class of food ingredient. The feasibility of extracting AX from sugarcane bagasse will be demonstrated, and the extracted material characterised for molecular weight and structure. Enzymes that target the ferulic acid linkages between AX and lignin will be applied to enhance AX extraction from both sugarcane bagasse and wheat bran. A larger scale trial will produce sufficient material to allow the functionality of the extracted AX as a bread ingredient to be demonstrated. The residual lignin, which has been partially deconstructed by the AX extraction process, will be examined for its suitability as a feedstock for conversion into a phenolic monomer using an existing reaction sequence. A techno--economic analysis will consider the broad economic viability of the proposed integrated process and its environmental implications.

Public Project Outcome

Arabinoxylans (AX) are a promising co-product of integrated ethanol biorefineries in which ethanol is used to precipitate the AX, giving a commercially viable context in which a new class of functional food ingredients might be produced. This proof-of-concept project demonstrated that AX could be extracted from sugarcane bagasse as well as from wheat bran, and that extraction yields and extract properties could be enhanced and refined through the application of feruloyl esterase and xylanase enzymes. Bagasse contained higher quantities of arabinoxylans (AX) with a much lower A:X ratio than wheat bran and gave higher yields on extraction. Scale-up issues were addressed and extracts produced at a scale and purity suitable for further evaluation as food ingredients. The lignin in the residue following AX extraction was evaluated for its suitability for further processing into valuable monomers. Wheat bran contained little usable lignin, while the lignin in bagasse was suitable for controlled depolymerisation into valuable monomers. Opportunities for enhanced economics through integration of the ethanolic streams were identified and optimised using pinch analysis. The project strengthened the evidence base for seeking to establish commercial processes for AX production and markets for its use, and enhanced the scientific and engineering bases for continued research towards that end.

Title: Integrated catalytic processing of lignin

Lead applicant: Gill Stephens, University of Nottingham	**Other Applicants:** Sankar Meenakshisundaram, Cardiff University; Nicholas Westwood, University of St Andrews; Mario De Bruyn, University of York

Public Summary

Lignin is a naturally occurring aromatic polymer, and forms a significant component of wastes from agriculture, forestry, food processing and biorefining. It is currently burned as a fuel, but process economics would be improved significantly if the Polymer could be Broken down To form value---added aromatic monomers. Unfortunately, chemical and enzymatic processes for lignin degradation are too inefficient, in isolation, for such processes to be cost effective. In this project, we will undertake a preliminary study to integrate chemical and enzymatic processing, to improve the efficiency of lignin depolymerisation by incorporating these complementary, Synergistic approaches. We will develop sequential Processes where An enzyme (laccase) is used To pretreat lignin, followed by Chemical catalysis to break the lignin down further. We will also investigate the opposite sequence: catalytic pretreatment followed by enzymatic treatment. Because naturally---occurring lignin is complex and variable, we will use simpler lignin model compounds as the substrate. This study will indicate the feasibility of integrated processing. In follow---on projects, We aim to Develop flow reactors for efficient, one---pot, enzymatic and chemocatalytic processing of native lignin.

Public Project Outcome

Society relies on the oil refinery as the generator of the fuels and chemicals that drive our everyday lives. In an attempt to spread the risk associated with our reliance on oil refineries, the concept of the biorefinery has emerged. The real challenge associated with the development of biorefineries is their economic viability. Many believe biorefineries can only be economically viable if every component of the starting biomass is used to its maximum potential. Whilst the use of the cellulose fraction from biomass is well developed, how we maximise the use of the lignin component is far from clear. One option is to breakdown this aromatic polymer into smaller pieces using state of the art catalytic methods. An ideal process for depolymerising lignin would involve the formation of small numbers of pure compounds. In this PoC project we explored possible strategies for the processing of lignin that are referred to as "tandem catalytic approaches". This means that two or more catalytic processes are combined to achieve difficult reactions. We studied two approaches to this. In the first an enzyme-mediated biocatalytic process was followed by a chemical process and in the second these steps were reversed. Significant process was achieved and it became clear that a modified biological system based on an enzyme called a laccase could be of real relevance to this process. Whilst there remains much to be done, this study has successfully focused our attention on the best path forward.

Title: LBNet Feedstock Resource	
Lead applicant: Claire Halpin, University of Dundee	**Other Applicants:** Tim Bugg, University of Warwick; Alessandra Devoto, Royal Holloway, University of London
Public Summary This project begins to address the research challenge of determining the influence of lignin content and composition on the deconstruction and efficiency of recovery from plant biomass of chemicals of interest to LBNet members. It will provide a common set of novel feedstocks with manipulated and distinct lignins to several LBNet members allowing results from different downstream processing regimes to be compared, thus adding value to the research of several partners. The idea is two-fold: (1) To produce larger quantities of modified barley straw from existing GM barley lines with novel lignins (including high H lignin, high G-lignin, high aldehyde lignin, reduced lignin content) so that a common set of materials can be used by different LBNet partners; and (2) to expand this set of lines by producing a high S lignin line with more linear and uniform lignin.	
Public Project Outcome This project aimed to determining the influence that lignin, one of the major components of wood and straw, has on the ability to break down these materials and use them to make useful chemicals and products. We have produced common set of novel straw feedstocks with different types of lignin that can be used by other laboratories to work out how different features of lignin affect straw breakdown and the chemicals they can release from it. By having a common set of materials the results of different breakdown processes can be directly compared.	

Title: Screening for new ligninase activities	
Academic Partner: Neil Bruce, University of York	**Other Applicants:** Simon McQueen-Mason, University of York; John Ralph, University of Wisconsin; Leonardo Gomez, University of York; Gordon Allison, Aberystwyth University; Phil Metcalfe, Efficiency Technologies; Mark Gronnow, BDC; Mario De Bruyn, University of York
Public Summary As fossil fuel supplies dwindle and concerns increase about the environmental impact of chemical waste streams, industrial biotechnologists are exploring ways to use plant based feedstocks in 'biorefineries' to generate biofuels and manufacture polymers, pharmaceuticals and commodity chemicals. The long-term success of biorefining is dependent on the development of economical methods for processing plant biomass to exploit the energy rich polysaccharides in cellulose for fermentation. The complex phenolic polymers present in lignin create a major bottleneck in the deconstruction of plant cell walls, as they are recalcitrant to degradation. The lignin component of plant cell walls does, however, also represent the largest global resource of natural aromatics that can potentially be liberated for the production of high-value chemicals if suitable enzymes could be identified with utility for lignin-based industrial processes. While the breakdown of lignocellulose remains a problem for industry, it is carried out effectively in the natural environment by microbial communities. The proposed PoC project builds on prior work where we have been exploring the proteome from complex microbial composting communities to identify new lignocellulose processing systems. From a wheat straw composting community containing over 2,500 microbial species we have identified >2000 proteins in the secreted proteome of which approximately 10% are known activities associated with lignocellulose metabolism, including ligninases. Over 800 of the proteins in the secretome have unidentified activities/function. The research proposed here, in this multidisciplinary collaboration, is concerned with developing a high-throughput assay to identify new lignin processing enzymes that have industrial application from this microbial community.	
Public Project Outcome Lignin is a complex aromatic heteropolymer that is enzymatically synthesised by coupling of three monolignol precursors p-coumaryl, coniferyl and sinapyl alcohols. A recent important discovery has demonstrated that grasses have the flavonoid tricin incorporated into the lignin. Tricin is recognised as an important and valuable health compound, with known anticancer, antioxidant and antiaging properties. Tricin is therefore an attractive target that could considerably increase the economic value of lignocellulose if a robust inexpensive process for tricin extraction	

could be developed. We identified a fungus *Graphium* sp. from compost that is able to grow on wheat straw and identified a new enzyme activity that can cleave the type of bond that incorporates tricin into the lignin polymer. A detailed characterisation of this biotechnologically important activity is currently underway.

Title: Clean and energy-efficient processing of ligno-cellulosic renewable biomass suitable for the Personal Care and High Performance materials markets: "Explosion to Implosion"

Lead applicant: Keith Waldron, Biorefinery Centre, Institute of Food Research	**Other Applicants:** Philip Metcalfe, Efficiency Technologies Limited; David Grainger, Unilever; Gerard Fernando, University of Birmingham; Claire Halpin, University of Dundee

Public Summary

The aim of this project is to enhance the utilisation of lignocellulose by improving the processing conditions. The objective is to combine novel and energy efficient physical pre-treatments, with conventional hydrothermal pre-treatments for lignocellulose to reduce the overall energy use and produce higher quality products. These are expected to contain lower or negligible quantities of chemically degraded components.

It is envisaged that this approach will:

Reduce the total energy requirement and saving costs;

reduce the production of fermentation inhibitors and related degradation products and

produce a less contaminated and coloured residue opening up new product opportunities for exploiting lignin residues in the health care, personal care, and nano materials markets.

Public Project Outcome

The aim of this project was to employ state-of-the-art analytical techniques to compare the effectiveness of HDC and an established process (hydrothermal extraction and/or steam explosion) on the pre-treatment of straw biomass in relation to enzymatic saccharification and quality of lignincontaining co-products. The results have demonstrated that whilst HDC does not emulate steam explosion-type pretreatments in relation to saccharification, it does impose interesting changes on the structure of the products. This opens further areas for research and development.

Title: Valorisation of lignocellulosic biomass using anaerobic fermentation

Lead applicant: Klaus Winzer, University of Nottingham	**Other Applicants:** Dana Heldt, Chain Biotech Ltd; Leonardo Gomez, University of York; Jason Hallett, Imperial College London

Public Summary

There is an urgent need to develop ecologically and economically sustainable routes to the production of fuels and chemical commodities, as fossil resources are limited and continued release of greenhouse gases is threatening the stability of the world's climate.

One way towards this goal is the development of microbial-based processes for the conversion of non-food lignocellulosic biomass into desirable products. Deconstruction of lignocellulosic biomass liberates sugars and other compounds which can be used by microorganisms such as yeasts and bacteria to generate a wide variety of interesting chemicals. Unfortunately, however, efficient lignocellulose breakdown relies on chemical and/or physical pre-treatment procedures that, in addition to the desired sugars, liberate toxic by-products which inhibit microbial growth. In addition, many microorganisms find it difficult to efficiently utilise the complex mixtures of different types of sugar which are released as part of the process.

In the proposed study we hope to address these issues by screening a large collection of butanol producing bacteria, many of which grow well on complex sugar mixtures. We hope to identify novel inhibitor-tolerant species that can convert these sugars to butanol and/or other valuable chemicals with high efficiency. We will also degrade lignocellulose using liquid salts, which will hopefully result in reduced inhibitor content. A major obstacle is that our bacteria are very sensitive to oxygen and can therefore not be screened using conventional high-throughput screening platforms. As part of the proposed work we will test and validate a new system that has been customised to our specifications

Public Project Outcome

There is an urgent need to develop ecologically and economically sustainable routes to the production of fuels and chemical commodities, as fossil resources are limited and continued release of greenhouse gases is threatening the stability of the world's climate.

One way towards this goal is the development of microbial-based processes for the conversion of non-food biomass and various wastes into desirable products. Deconstruction of lignocellulosic biomass liberates sugars and other compounds which can then be used by microorganisms such as yeasts and bacteria to generate a wide variety of interesting chemicals. However, efficient lignocellulose breakdown relies on chemical and physical pretreatment regimes that, in addition to the desired sugars, liberate toxic by-products which inhibit microbial growth. In addition, many microorganisms find it difficult to efficiently utilise the complex mixtures of different types of sugars which are released as part of the process.

In our study we have addressed these issues by testing the performance of a large collection of butanol producing bacteria when grown on sugar mixtures generated through different pretreatment regimes. We established that butanol producing bacteria grow generally well on biomass pretreated with alkali and identified several high performing strains as promising candidates for future, larger scale fermentations. A major challenge was that our bacteria are very sensitive to oxygen and cannot be screened using conventional high-throughput platforms. Here, we tested a customised screening platform and found that whilst performance was adequate it might be further improved through a number of technical adjustments.

Title: Engineering pathways for targeted lignin degradation in *C. necator* towards the production of pyridine dicarboxylic acids as bio-polymer monomers.

Lead applicant: Sam Bryan, University of Nottingham	**Other Applicants:** Alex Conradie, University of Nottingham; Paul Mines, Biome Technologies

Public Summary
Lignin represents a renewable carbon feedstock that has transformative potential as a replacement for petroleum carbon feedstocks. However, approximately 50 million tonnes of lignin is produced worldwide as a poorly valorised waste product. Lignin is comprised of aromatic monomer building blocks. To produce economically viable lignin-derived biochemicals, these monomers must be selectively released from the lignin and utilised as a carbon source by microorganism cell factories. Cupriavidus necator is a robust, metabolically diverse microorganism cell factory, capable of utilising aromatic monomers as carbon sources; however, C. necator is unable to degrade lignin. This makes C. necator an ideal candidate to introduce selective and targeted lignin degradation via metabolic engineering. We anticipate that our research will be at the forefront of generating a metabolically engineered strain capable of breaking down lignin and utilising the monomers to make industrially relevant products, which will have a major impact on next generation biopolymers in particular.

Public Project Outcome:
Lignin represents a renewable carbon feedstock that has transformative potential as a replacement for petroleum carbon feedstocks. However, approximately 50 million tonnes of lignin is produced worldwide as a mostly non-valorised waste product. Lignin is comprised of aromatic monomer building blocks. Producing economically viable lignin-derived biochemicals, these monomers must be released from the lignin and utilised as a carbon source by microorganism cell factories. *Cupriavidus necator* is a robust, metabolically diverse microorganism cell factory, capable of utilising aromatic monomers as carbon sources; however, *C. necator* is unable to degrade lignin. This makes *C. necator* an ideal candidate to introduce selective and targeted lignin degradation via metabolic engineering.
This BBSRC-sponsored LBNet project has established lignin degradation in *C. necator* as a sustainable carbon feedstock for the production of compostable bioplastics. The biochemical processing route has been enabled via the lignin monomer, vanillin, in the microbial cell factory. Commercialisation of the process will enable the production of food packaging from sustainable sources as a successful project aligned with the UK government's *Clean Growth Strategy* and *Industrial Strategy*.

Title: Advanced Biorefining for High Value Chemical Production

Lead applicant: Ying Zhang, University of Nottingham	**Other Applicants:** Nigel Minton, University of Nottingham; Alex Conradie, University of Nottingham; Dana Heldt, CHAIN Biotech

Public Summary
Biofuel production and renewable chemical manufacture offer sustainable routes to reduce greenhouse gas (GHG)

emissions and mitigate against global warming. The use of plant based feedstocks i.e. agricultural and forestry residues and municipal wastes provide attractive feedstocks but cost-competitive biorefining also requires efficient process conversion technologies for both pre-treatment/hydrolysis and sugar fermentation plus reuse and recycle of fermentation by-products. In this project, we focus on the fermentation stage and more specifically on the development of a novel fermentation process to produce a high value chemical (R)- 1,3-Butanediol ((R)-1,3-BDO). We build on advances with the Clostridia butanol fermentation which has been proven on a wide range of cellulosic feedstocks, including wheat straw and municipal solid waste, and scaled up to commercial scale. We plan to use advanced synthetic biology tools to develop and demonstrate robust industrial Clostridium strains to produce (R)-1,3-BDO at high yield and titre. Ultimately, we aim to improve the economics of fermentation and biorefining by producing a new and higher value chemical product and developing a process concept to utilise all the fermentation by products including waste gases CO2 and H2

Public Project Outcome

With the reaching of peak-oil and the concomitant decline of the world's major resource for the manufacturing of chemicals new solutions for valuable molecule production have to be found. Biofuel production and renewable chemical manufacture offer sustainable routes to reduce greenhouse gas (GHG) emissions and mitigate against global warming. In this project, we focused on the development of a novel fermentation process to produce a high value chemical (R)-1,3-Butanediol ((R)-1,3-BDO), a key building block for pheromones, fragrances, insecticides and a key intermediate of penem and carbapenem β-lactam antibiotics. We built on advances with the Clostridia butanol fermentation which has been proven on a wide range of cellulosic feedstocks, including wheat-straw and municipal solid waste, and scaled up to commercial scale. We have implemented the route to (R)-1,3-BDO in a robust industrial relevant Clostridia, and further increased product levels by 60% compared to the initial attempt. We further modulated key enzyme expression by choosing different strength promoters from an exhaustive promoter library which further increased products yields. Finally, the deletion of key steps of the central energy pathway improved our understanding of this industrially important whole cell biocatalyst which will be used to further increase (R)-1,3-BDO titres.

Title: Assessing the suitability of wood pellets for use in biorefining to produce fuels, chemicals and electricity

Lead applicant: Simon McQueen-Mason, University of York	**Other Applicants:** n/a

Public Summary

The UK is home to some very large biomass power stations. For example, Drax is the biggest biomass power plant in Europe, burning over 7 million tonnes of wood pellets per year to generate renewable low carbon electricity. In a previous desk-based study we concluded that it would be possible for such a power station to use a sugar rich fraction of its biomass feedstock to produce sustainable liquid biofuels, before a lignin rich residue was combusted to produce electricity. We also concluded that this biomass biorefining approach could increase the profitability of such activities. In our assessment, we considered that such a biomass power station would be uniquely placed to produce sustainable commercial biofuels in the UK due to its potential to operate at a scale large enough to minimise the costs of capital investment (as a percentage of turnover) through its access to certified sustainable feedstock round the year through biomass contracts, and through the biomass logistical infrastructure being already established. The biggest uncertainty in our initial feasibility study come from lack of data on the efficiency with which the wood pellets can be processed into bioethanol. This information is key to carry out the high level techno-economic assessment needed for taking the concept forward. We therefore are requesting research funds to undertake laboratory and pilot scale analysis of the efficiency with which bioethanol can be produced from wood pellets, and of the energy balance in the lignin residue after bioethanol production that will be used for electricity generation. This information will constitute an empirical evaluation of integrated biofuel and electricity production at a major biomass power station.

Public Project Outcome

This report considers the viability of integrating a second generation bioethanol plant into the Drax site, using data generated at pilot scale. The model is based on using one million tonnes softwood pellets from their existing supply chain and technology. It uses figures for CAPEX and OPEX from the USA's National Renewable Energy Laboratory (NREL) 2011 report on the production of bioethanol from corn stover and current spot prices for products (£50/MWh for electricity; £338/ton for ethanol and £25/ton for CO_2).

For the pilot scale work, five pre-treatments have been evaluated with the two most promising being water at room

temperature and acetic acid at 150 °C. The volume of ethanol produced ranged from between 23 and 21 g/l, respectively. This equates at a 1 million tonnes scale generation of 139,000 and 134,000 tonnes per annum, respectively, of lignocellulosic ethanol. The model assumes that the remaining lignin residue is used for electricity generation.	
Title: High value semiochemicals from UKBIOChem10 platform molecule Levoglucosenone through industrial biotechnology	
Lead applicant: David Withall, Rothamsted Research	**Other Applicants:** Fabien Deswarte, Circa Sustainable Chemicals Ltd
Public Summary Circa Sustainable Chemicals Ltd have developed the world's first and only continuous process to manufacture the UKBIOChem10 platform molecule Levoglucosenone (LGO) from wood waste. This is now available in commercial quantities from their demonstration plant in Tasmania. This project aims to assess the potential of producing high value semiochemicals from this highly functional and chiral building block using industrial biotechnology. The use of semiochemicals as a means of monitoring and controlling pest populations, using baited lures, mass trappings and mating disruption, is attracting significant commercial interest as a more environmentally friendly method of pest control and is increasingly being used commercially. However, the structurally complex nature of semiochemicals and their stereochemistry pose a challenge for their large-scale production. Owing to its unique structural characteristics (including two distinct chiral centres retained from cellulose), LGO represents an ideal candidate for investigation as a building block for enantiomerically pure pheromone production using novel stereoselective biotransformations.	
Public Project Outcome The aim of this collaborative research project between Rothamsted Research and Circa Sustainable Chemicals Ltd was to evaluate the possibility of using UKBIOChem10 platform molecule Levoglucosenone (LGO), derived from wood waste, as a feedstock for high value semiochemicals for applications in Integrated Pest Management (IPM) strategies. Such IPM strategies are more environmentally friendly than traditional pest control technologies, by manipulating pest populations through mating disruption, mass trappings and recruitment of beneficial organisms. This research project has successfully prepared semiochemicals that are currently used commercially to control an invasive pest that affects a huge number of ornamental plants, vegetables, trees and shrubs. Our work has demonstrated the ability to prepare the active compound in an optically pure state from LGO, essential to achieve the desired biological effect. Additionally, we have identified a second target compound to be prepared from LGO that could be deployed with current biopesticide based control technologies, enhancing their effectiveness in controlling fly pests.	
Title: ABE fermentation of hydrolysates derived from heavy metal polluted waste wood after ionoSolv™ fractionation and steam explosion	
Lead applicant: Jason Hallett, Imperial College London	**Other Applicants:** Jagroop Pandhal, University of Sheffield; Phillip C Wright; Newcastle University; Agi Brant-Talbot, Imperial College London; Mahendra Raut, University of Sheffield; Florence Gschwendc, Chrysalix Technologies; Mark Christensen, BioSci Ltd
Public Summary 50% of wood waste is currently not recycled but instead goes to landfilling or incineration due to contamination with unwanted matter, incurring disposal fees. Converting wood-waste into the bio-based chemicals butanol, acetone and ethanol would create a re-use option for this wood waste while increasing the amount of sustainable bio-derived products available. However, a major challenge for the bioconversion of unwanted and hazardous (Grade C and D) wood waste is the presence of heavy metals from paints and preservatives. This project explores the use of inexpensive recyclable ionic liquids (IL) and steam explosion as a pre-treatment that will condition wood waste effectively for microbial conversion to butanol and other products. The pretreatment will separate the wood waste into its main components and remove the heavy metals present in the waste wood. The wood-waste derived sugars will then be converted to the products using the bacterium Clostridium acetobutylicum. A preliminary techno-economic assessment will be carried out to assess the production cost of this new method and compare the new approach using agricultural straws and steam explosion only. Success will provide a new avenue for a low cost bioprocess for the production of a bio-derived chemical that the UK is a leader in. It will also provide an opportunity to scale-up the wood waste bioprocessing to industrial levels, while engaging universities and businesses in bioprocess optimisation.	
Public Project Outcome: to follow	