Project report: Sustainable Production of High-Quality Second Generation Transport Biofuels from Mallee Biomass by Pyrolysis and Biorefinery

Lead organisation: Curtin University of Technology

Project partners: CSIRO Sustainable Ecosystems and Western Australia (WA) Department of Environment and Conservation

Project commencement and completion date: September 2009 – May 2012

Project summary

The project developed a new technology and increased technical know-how that will equip Australia to grow and convert farm-grown mallee crops (biomass) into advanced biofuels, thereby helping to meet transport fuel demands while reducing carbon emissions.

It was fundeded through the Second Generation Biofuels Research and Development (Gen 2) Program, which supported the research, development and demonstration of new biofuel technologies and feedstocks that address the sustainable development of an advanced biofuel industry in Australia.

The project had three key outcomes:

1. It successfully developed a unique technology that combines heating (pyrolysis) of mallee crops and the subsequent biorefinery of the resulting green bio-crude to sustainably produce advanced biofuels. The key features of the technology have been demonstrated in lab-scale pilot plants.

The project found that depending on the biorefinery configuration the cost of producing biofuels could be as low as 49 cents a litre when converting mallee biomass grown in the WA wheatbelt. In addition, the overall net carbon emission of biofuel production could be negative: significant amounts of CO_2 from the atmosphere could be sequestrated during the overall process of biofuel production if bio-char is returned back to the field.

2) It increased understanding about how mallee biomass could be produced at an affordable price and at a large enough scale for biofuel production. An additional benefit is that mallee biomass production can help address dryland salinity problems and support regional economies.

3) It also generated significant amounts of new knowledge and intellectual property.

Many young scientists and engineers, including PhD students, were involved in this project. The research training they received is a vital contribution to the emerging advanced biofuel industry in Australia. Two patent applications have been filed on the prolysis and biorefinery technology that was developed during the project.

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Curtin University

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Project scope

The project developed a new technology that produces advanced biofuels from mallee crops through pyrolysis (heating in the absence of oxygen) followed by upgrading (biorefinery) of the pyrolysis green bio-crude. Key features of the pyrolysis and biorefinery technologies were demonstrated using laboratory-scale pilot plants. The project also investigated mallee crop production systems and developed a decision support tool to help farmers estimate yield using key site characteristics.

An additional benefit that arose from the project was that the overall CO_2 emissions can be reduced by returning the bio-char product from the new technology back to the field for soil conditioning and carbon bio-sequestration. By helping absorb CO_2 from the atmosphere, the process can produce advanced biofuels with much lower emissions than the fossil fuel alternatives. The technologies developed in this project, combined with the knowledge and skills gained, will make a significant contribution to the establishment of an advanced biofuel industry in Australia.

Outcomes

Advanced biofuel technology development:

The project successfully demonstrated the technical feasibility of a novel two-step pyrolysis-biorefinery technology.

Biomass grinding pyrolysis technology:

A biomass grinding pyrolysis technology was successfully developed and demonstrated using a purpose-built pilot plant at a biomass feeding rate of more than 15 kg/hr. The technology can be used for the production of bio-oil (i.e. green bio-crude), which can be further upgraded into biofuels that can be 'dropped-in' to existing fuel infrastructure, known as "drop-in" biofuels.

The grinding pyrolysis technology can also be used for the co-firing of biomass and coal in the existing coal-fired power plants and for the co-gasification of biomass and coal in a gasifier.

Biorefinery technology:

The project included an extensive study of the acid-catalysed reactions between pyrolysis green bio-crude and alcohol (methanol), which transform methanol into a much better liquid fuel. A novel process (bio-crude hydrotreatment reactor configuration) was also developed to produce drop-in biofuels using cheap catalysts. This reduced coke formation on catalyst surface and increased energy efficiency.

Bio-char for soil amendment and nutrient recycling:

The bio-char product of the pyrolysis process can be mixed back into the soil for nutrient recycling, soil amendment and carbon bio-sequestration. Bio-char can also be sold as a fuel, a reductant in the metallurgical industry, or for use in the production of activated carbon and other carbonaceous materials.

The leaching of nutrients from bio-char samples produced under a wide range of conditions was investigated for the use of bio-char as a vehicle for the returning of nutrients back into the field in order to enhance the sustainability of biomass production. The project results provide useful guidance for the use of bio-char for soil amendment in addition to its function for carbon bio-sequestration.

Economic and life cycle performance of our biofuel technology:

The project confirmed the economic attractiveness of advanced biofuel production from mallee biomass. Using mallee biomass grown in the WA wheatbelt, the liquid biofuel production costs could be as low as A$ 0.6 per litre (equivalent to A$17.2 per GJ energy in biofuel) for one-step biorefinery (hydrotreating), and A$0.49 per litre (equivalent to A$17.6 per GJ energy in biofuel) for two-step biorefinery (esterification and hydrotreating).

When carbon bio-sequestration is taken into consideration by returning the bio-char back to the field, up to 1.3 kg of carbon dioxide (or its equivalent) in the atmosphere for one-step biorefinery and 0.6 kg of carbon dioxide (or its equivalent) in the atmosphere for two-step biorefinery can be sequestrated for every litre of biofuel produced. Those are equivalent to 39.3 and 22.4 kg of sequestrated carbon dioxide (or its equivalent) for every GJ of biofuel produced from one-step biorefinery and two-step biorefinery, respectively.

Mallee biomass production

This project has led to improved understanding and the development of key knowledge that can enhance the economically viable and sustainable production of mallee biomass as a component of wheatbelt agricultural systems. Major advances include the modification of mallee belt orientation, configuration and nutrient application. These will improve the capture of run-off water and management of any impacts on adjacent conventional agriculture to lower costs and increase biomass yield. This will increase the viability of the mallee biomass industry for both growers and processors.

Products, patents (applied/granted) and publications produced as part of the project

Products

This project has resulted in the development of a decision support tool for use by growers to estimate mallee production based on key site characteristics. This tool will be made directly available to farmers to speed up the development and capacity for the mallee-based biofuel industry.

Patents

Two patent applications have been filed on pyrolysis and biorefinery respectively:

- WO2011160163, Method of and system for grinding pyrolysis of particulate carbonaceous feedstock
- A method of hydrotreatment and a hydrotreatment system

The first patent has been published, which will facilitate the technology transfer and commercialisation of the technology developed in this project.

Papers and reports

The project has generated significant amounts of new knowledge and intellectual property (including know-how). Numerous scientific papers on the project findings have been published in international journals with additional ones currently being prepared. Two key reports have been prepared for publication.

Ancillary benefits

Many young scientists and engineers, including PhD students, were involved in this project. The research training they received as a result of this project is a further vital contribution to the emerging advanced biofuel industry in Australia.

Minister Ferguson launched the Biofuel Research and Development Facility in Curtin University of Technology in 2012 in recognition of the University's progress in advanced biofuels. The facility will continue to be an incubator of new ideas and new technologies to serve the needs of the emerging advanced biofuel industry in Australia.

The project personnel have continued to maintain close links with mallee-growing farmers, inviting them to see research sites and consider results such as the decision support tool, thus facilitating the direct transfer of the new knowledge from this project to its users.

Effectiveness

The biomass grinding pyrolysis technology was successfully developed and demonstrated using a purpose-built pilot plant at a biomass feeding rate of more than 15 kg/hr. The technology can be used for the production of green bio-crude, bio-char, and for the co-firing and co-gasification of biomass and coal in coal-fired power plants and gasifiers respectively.

An extensive study was carried out to investigate the acid-catalysed reactions between pyrolysis green bio-crude and alcohol (methanol). The reactions also incorporated methanol into a much better liquid fuel. The project also investigated the hydrotreatment of bio-crude under a wide range of conditions at scales up to 5 L/hr.

Analysis confirmed the economic attractiveness of advanced biofuel production from mallee biomass. Depending on the biorefinery configuration, the liquid biofuel production costs could be as low as $0.49/L using mallee biomass grown in the WA wheatbelt as the feedstock. If considering carbon bio-sequestration by returning bio-char back to the field up to 1.3 kg CO_2-e in the atmosphere can be sequestrated for every litre of biofuel produced depending on the biorefinery configuration.

The leaching of nutrients from bio-char samples produced under a wide range of conditions was investigated for the use of bio-char as a vehicle for returning nutrients back into the field in order to enhance the sustainability of biomass production. The results provided useful guidance for the use of bio-char for soil amendment in addition to carbon bio-sequestration.

The growth of mallee biomass will greatly help to combat dryland salinity, which threatens the sustainability of Australian agriculture and regional areas. A biomass-biofuel value chain would also foster regional development by creating additional jobs in regional Australia.

Transferability

Much of the knowledge and biofuel production technology obtained in this project can be applied to the production of advanced biofuels from other types of lignocellulosic biomass.

Conclusion and next steps

The Biofuel Research and Development Facility established at Curtin University of Technology will be an incubator of new ideas and new technologies to serve the needs of an emerging advanced biofuel industry in Australia.

All project participating organisations are committed to the long-term development of an advanced biofuel industry. Following consultation with key stakeholders, Curtin University of Technology has formulated a business plan for the commercialisation of the biofuel technology developed in this project. It will play a pivotal role in the establishment of an advanced biofuel industry in Australia.

Curtin's biofuel technology has been developed, but will not be limited to, using mallee biomass. Efforts will be made to incorporate other types of biomass feedstock in further development and demonstration of this biofuel technology.

Efforts will also be made to explore commercialisation of the technologies developed in this project for applications beyond liquid biofuels, for example, the use of our grinding pyrolysis technology in the co-firing of biomass and coal in coal-fired power stations.

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