Biofuels and Transport: An Australian opportunity

A special report from the CEFC and ARENA

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Tapping Australia's biofuels potential

A message from the CEFC and ARENA

With Australia's electricity sector undergoing a substantial transition to cleaner energy and lower emissions, it is appropriate to consider other areas of emissions reduction that will be essential for Australia to meet our emissions reductions commitments.

Transport is one such area of opportunity, particularly when supported by a robust domestic biofuels industry.

Together, the CEFC and ARENA commissioned new analysis to help the industry, investors and policy makers anticipate the potential pathway to a biofuels-rich transport sector. Market experts GHD bring a global view to this challenge, considering the experience of other markets and identifying opportunities for the nascent biofuels industry in Australia.

Globally, biofuels production is projected to increase 10-fold by 2060, making it a major player in decarbonisation of transport worldwide. However, for Australia to contribute its share of that output, we would need to experience a 40-fold expansion of our industry over the same period, to reach an annual production capacity of 20 gigalitres.

Advanced biofuels can derive energy from feedstocks that would otherwise be considered waste materials. They are also highly compatible with existing fuel infrastructure, which further increases their attractiveness for investment. Australia's existing experience in agriculture, forestry and engineering provides a solid foundation on which to build a thriving biofuels industry. And our heavy reliance on air travel, long-distance road freight and rail and marine freight, provide the potential demand for these lower emissions biofuels.

Developing this industry presents opportunities to provide new and ongoing industrial employment in regional areas. To meet a 20 gigalitre annual production target it is estimated up to 250,000 jobs could be created and the investment required by production facilities alone is estimated at between $25 billion and $30 billion. But support from a range of quarters is needed to achieve such an outcome and to drive down the cost of production so that biofuels are competitive with petroleum fuels.

To build this industry at the required scale, Australia will benefit from early investment in first-of-their-kind facilities to ensure training and skills development occur domestically. ARENA has the experience and capacity to provide funding to research and development and pilot models. The CEFC can further support developers with finance tailored to meet individual project needs.

We trust this report provides useful insights into the industry's potential and look forward to working further with biofuels project developers to accelerate Australia's transition to affordable and reliable renewable energy sources as part of a lower emissions economy.

Australian biofuels: a new frontier

Key findings of the report:

1. The international transport sector produces 15 per cent of carbon emissions and 23 per cent of fossil fuel emissions globally.[1] In Australia, transport is the second-largest carbon emitter, responsible for 18 per cent of national emissions.[2] In light of global climate change challenges, the transport sector's emissions must decrease. The challenge is reducing these emissions without impacting the sector's utility. One solution is to develop a thriving biofuel industry in Australia.

2. The International Energy Agency (IEA) identifies biofuel as a major player in the decarbonisation of the transport sector.[3] The IEA projects global annual biofuel production will increase tenfold to 840 gigalitres by 2060.[4] As a proportion of all fuel, the amount of biofuel currently produced in Australia sits below the global average. For the nation to contribute its share of the projected global average in 2060, it needs to increase its biofuel production by a factor of 40 to approximately 20 gigalitres per year.

3. Australia's many geographic, climatic, resource and research advantages should enable it to meet this challenge and become a leader in the field. Australia can also draw on the experience of its small but resilient core biofuel industry. Global employment figures suggest an Australian biofuels production target of 20 gigalitres per year could provide long-term employment for up to 250,000 people, mostly in regional areas.

4. Australia's geography necessitates its heavy reliance on air travel, long-distance road freight, and rail and marine freight. Electrification is expected to have a significant impact on the light vehicle transport sector. However, liquid fuels are projected to remain the most commonly used fuels in the heavy freight, shipping and aviation industries as they have high energy-density and are convenient to store and handle. Biofuels offer a sustainable, low-carbon alternative for these industries.

5. Cost competitiveness is the biggest barrier to biofuel expansion. Support is needed to help bring down the cost of developing biofuel technologies, recognising the potential environmental, socioeconomic and geopolitical benefits. Nations with successful biofuel industries have demonstrated the importance of appropriate policy and regulation for maximising biofuel's positive financial and environmental outcomes.

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[1] IEA (2017), Energy Technology Perspectives: Tracking Clean Energy Progress 2017.

[2] Department of the Environment and Energy (2017), Australia's Emission Projections.

[3] IEA (2017), Energy Technology Perspectives: Tracking Clean Energy Progress 2017.

[4] One gigalitre (GL) is equivalent to one billion (1,000,000,000) litres

6. A scenario analysis of future biofuel costs indicates that advanced biofuels are likely to become cost competitive with petroleum fuels, just as wind and solar power generation have become cost competitive with fossil fuels over the past 20 years.

7. The Australian transport sector's dependence on crude oil and fuel imports has grown from around 60 per cent in 2000 to more than 90 per cent today. Australia's fuel storage capacity is held within the commercial supply chain, with no government-held or compulsory industry stocks of emergency reserves. A readily available and sustainable substitute such as biofuel would alleviate some of the risk associated with Australia's almost total reliance on imported petroleum products.

8. To grow, the biofuel industry requires both industry and infrastructure development. Compared with other carbon mitigation options, this development needs a longer gestation period. Importantly, short-term policy development and technological support can enable biofuels to contribute to delivery of Australia's international emissions reduction commitments under the Paris Agreement.

9. A new generation of advanced biofuels capable of overcoming some of the limitations of conventional biofuels are being commercially developed. Advanced biofuels can be produced from a broader range of feedstock, including waste streams. They are also often fully compatible with existing fuels, which means they can be inserted into the existing delivery infrastructure.

10. In Australia, the focus for future biofuel developments should be on sustainable, low-carbon, advanced biofuels. Co-located conventional and advanced biofuel facilities, which combine economic returns with sustainability, could be a way forward. These could be modelled on existing bio-refinery systems, such as those that use the whole sugarcane plant to produce food products, conventional ethanol, cellulosic ethanol and renewable heating, cooling and power. The investment required by production facilities alone is estimated at between $25 billion and $30 billion.

Getting to know biofuels

Conventional biofuels

Conventional biofuels are usually considered to be biodiesel produced from vegetable oils or ethanol produced from sugarcane, corn or wheat. Due to their high oxygen and moisture content, sedimentation and cold flow issues, there is a limit to how well these fuels can blend with petroleum.

Conventional biofuels are:

- Referred to as first-generation biofuels
- Produced almost exclusively from the human food chain
- Includes ethanol from sugar (for example, from cane) or starch (from corn)
- Also includes biodiesel from oils and fats
- Not typically 100 per cent compatible with existing fuel infrastructure or with existing vehicles, ships and planes.

Advanced biofuels

Advanced biofuels include renewable diesel, green diesel, Fischer–Tropsch (FT)-diesel, bio-jet fuel, and bio-gasoline. They are compatible with the existing infrastructure that was designed around petroleum. These and other advanced fuels like cellulosic ethanol, bio-CNG and bio-LNG also have a much greater potential to reduce carbon emissions than conventional biofuels.

Advanced biofuels are:

- Referred to as second-, third- and even fourth-generation biofuels, depending on the type of feedstock used
- Produced from non-food feedstocks
- Includes residue from the forestry and agricultural sectors, including straw, cotton trash, sawdust and vegetation removed by agricultural thinning
- Also includes purpose-grown crops such as high-yield grass, woody biomass or algae, typically grown on semi-arable land
- Draws on eligible urban waste streams such as municipal solid waste (MSW) or household rubbish, and food waste streams such as corn stover (stalks, leaves and cobs left over after harvest)
- Compatible with existing fuel infrastructure, these biofuels are widely seen as ‘drop-in’ biofuels.

Why transport emissions matter

The global perspective

The International Energy Agency (IEA) 2°C scenario (2DS) outlines a deployment plan and emissions trajectory based on a 50 per cent probability that average global temperature growth will not exceed 2°C by 2100.[5]

In 2013, the transport sector was responsible for approximately 15 per cent of total global carbon emissions and 23 per cent of all global emissions from fossil fuels. The Organization of the Petroleum Exporting Companies (OPEC) projected that the global transport energy sector's needs would grow by approximately 23 per cent between 2015 and 2060.[6]

The transport sector must significantly reduce its emissions if it is to meet the IEA 2DS trajectory. Ideally, these cuts will not lead to significant cost increases, or reductions in the sector's utility.

Emissions reduction strategies include more efficient vehicle design, improved logistics, increased use of lower emission modes of transport and greater reliance on lowemission fuels such as biofuels. Other sources of lowemission power include renewable electricity (battery power), hydrogen, and compressed natural gas (CNG) or liquefied natural gas (LNG).[7]

Biofuels are an attractive option due to their high energy density and convenient handling and storage properties. They can also 'drop in' to the existing fuel supply and end-use infrastructure with minimal modification and expense required.

Current global biofuel production provides only 2.7 per cent (3.3 exajoules, equivalent to 92.4 gigalitres of diesel)[8] of the global transport sector's annual energy requirement.[9] Even with electrification and efficiency gains in transport technology, the IEA projects a 40-year, tenfold increase in annual biofuel production to 30 exajoules (equivalent to 840 gigalitres of diesel) will be necessary if the sector is to meet its 2DS target.

These benefits mean biofuels are likely to become significant contributors in the heavy freight, shipping and aviation sectors. Electric solutions are more likely to dominate the passenger, light commercial and rail sectors.

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[5] IEA (2017), Energy Technology Perspectives, Tracking Clean Energy Progress 2017.

[6] OPEC (2017), World Oil Outlook 2040.

[7] CNG/LNG vehicles have lower well-to-wheel greenhouse gas emissions than gasoline-powered vehicles, but higher than modern diesel vehicles. Alternative Fuels Data Centre, US DOE:

[8] One exajoule (equivalent to 1,018 joules) is equivalent to approximately 28 gigalitres of diesel fuel.

[9] IEA (2017), Energy Technology Perspectives, Tracking Clean Energy Progress 2017

Figure 1 OPEC projections of transport energy demand and IEA projection of global biofuel production to 2060

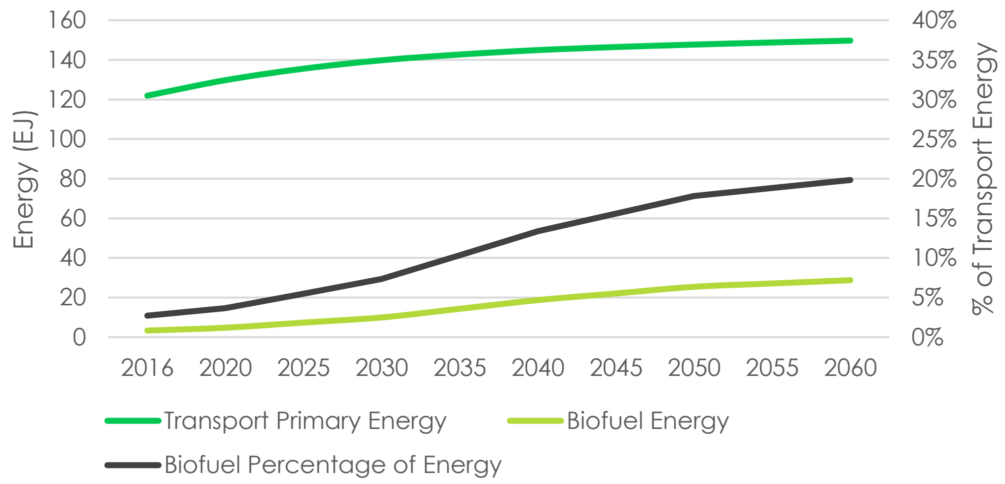
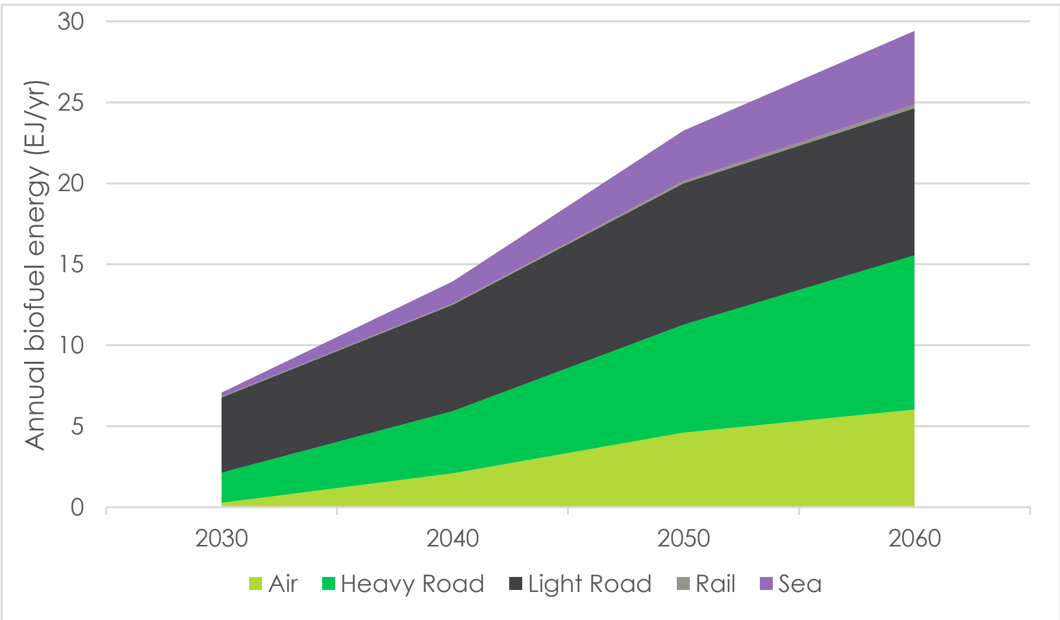


Figure 2 Global biofuels energy growth in transport, by market sector (IEA, 2017a)



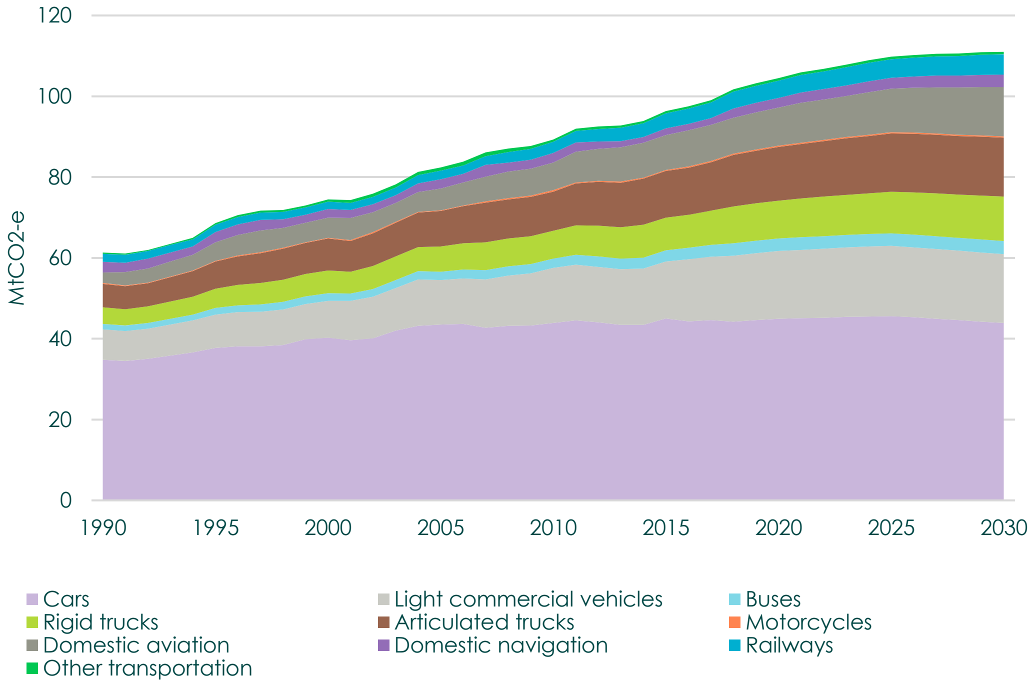
The Australian perspective

In Australia, the transport sector represented 27 per cent of total energy consumption in the 2014-15 financial year. In 2017, transport was the second-largest source of emissions, producing 18 per cent of Australia's total carbon emissions (100 million tonnes of carbon dioxide equivalent). Road transport was responsible for around 85 per cent of the sector's emissions, with air transport responsible for an increasing share of emissions.[10]

Cars are responsible for almost half (44 million tonnes) of all transport emissions. Emissions have increased by 22 per cent since 2005. As Figure 3 shows, greenhouse gas emissions from transport are projected to rise another 12 per cent by 2030, to 112 million tonnes, despite projected improvements in vehicle efficiency and increases in low-emission fuels.

Electrification is expected to impact the light vehicle transport sector. But liquid fuels, with their high-density energy and convenient storage and handling properties, are projected to continue dominating the heavy freight, shipping and aviation industries. Biofuels offer a sustainable, lowcarbon alternative.

Figure 3 Australia's carbon emissions from transport, 1990 to 2030



Source: Department of the Environment and Energy, 2017

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[10] Department of the Environment and Energy (2017), Australia's Emission Projections 2017.

Biofuels and sustainability

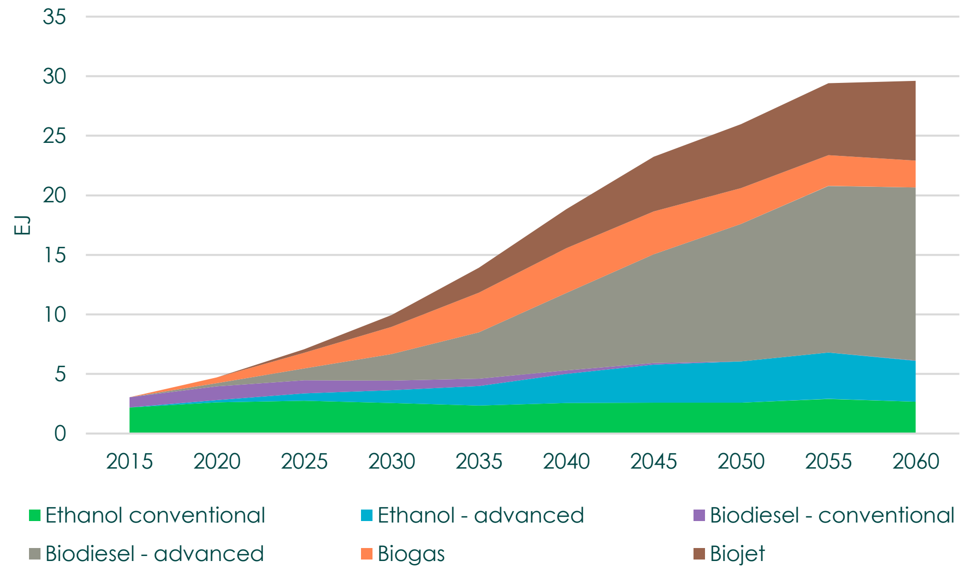
The IEA expects the majority of biofuel growth to come from advanced biofuels. In addition to financial and technical challenges, the developing biofuel industry needs to address the following sustainability considerations:

Food versus fuel. Biofuels should not diminish the food available to the growing global population. Feedstock for future biofuel production will need to come from non-food biomass (such as lignocellulosic material) or waste products (such as corn stover). Further technological development is needed to solve this potential problem.

Land requirements. It is estimated the biofuel industry will require approximately 100 million hectares to meet its 2060 target. This is a threefold increase on its current usage (30 million hectares or two per cent of global arable land).[11] This increase will occur at the same time as a growing global population seeks more arable land to produce food, fibre and biomass for bioenergy (heat and power). Ideally, the land required for biofuel feedstock production will be semi-arable and not compete with other demands for arable land. The disproportionate increase in biofuel production compared to the amount of land required is partly due to the significant increase in the use of waste products.

Energy efficiency. The energy required to produce or collect feedstock and convert it to fuel should only comprise a small proportion of the total energy in the final fuel. This was not the case with early commercial biofuel products. A key step towards improving the sustainability of biofuel production – and achieving greater energy density without greater energy use – is the transition from conventional to advanced biofuels.

Figure 4 Global biofuels energy growth by fuel type (IEA, 2017a)



[11] IEA (2011), Technology Roadmap: Biofuels for Transport

Alternative low emission fuel options

Electricity

As a transportation energy alternative, electricity offers two opportunities for emissions reduction:

1. decarbonised electricity for use in transport can be sourced from wind, wave, hydro-electric and solar power
2. electric motors are highly efficient at converting electrical energy into kinetic energy, with further efficiencies achieved as kinetic energy is recovered with regenerative braking

Continuing developments in electric drivelines and battery technology are likely to make electric vehicles an increasingly popular low carbon option in the passenger and road transport sectors.

Hydrogen

Hydrogen is an alternative energy carrier. Although it is presently produced mostly from natural gas, hydrogen can also be made from low carbon materials such as renewable electricity and biomass. Research into hydrogen's potential as a transport fuel is ongoing; investigators are exploring its use as a combustion fuel, a diesel supplement, or a component in fuel cell applications. Currently, the research is focused on hydrogen's use in fuel cell electric vehicles (FCEVs).

A major barrier to increased hydrogen use is its low density, which makes storage difficult. Researchers are looking at potential solutions like high-pressure storage, liquefaction and chemical storage such as ammonia. Other barriers include the cost of production, and the changes in distribution, refuelling and end-use infrastructure required if hydrogen is to be adopted widely.

Continuing advancements in hydrogen technology indicate that this low-carbon alternative has potential in the passenger, road transport and shipping sectors.

Global trends

Advanced biofuels gain momentum

Environmental, political and social drivers have shifted the focus of global biofuel developers from conventional biofuels – those produced from food crops and not 100 per cent compatible with existing infrastructure – to advanced biofuels created from non-food feedstocks. There is also a new focus on developing "drop-in" fuels – those compatible with existing engines and fossil fuel–based infrastructure.

Figure 5 Composition and end uses of conventional and advanced fuels:

CATEGORY	CONVERSION			FEEDSTOCK							END-USE-SECTOR		
	Fuel type	Technology	Example	Starch, sugar	Crop residue	Wood	MSW	Oils, fat, grease	Micro-algae	Sewage sludge	Passenger and LCV	Heavy freight, rail, marine	Aviation
	Ethanol	*Traditional fermentation*	*Green plains (USA) Gevo / Butamax*	X							X		
Conventional	*Butanol*	*Fermentation of sugar*	*Renewable*	X							X		
	Biodiesel	*Transesterification / Esterification*	*Energy Group*					X				X	
		Cellulosic Ethanol	*Raizen (Brazil)*		X	X					X		
	Ethanol	*Gas phase fermentation*	*LanzaTech (Global)*		X	X	X				X		
		Gas phase fermentation	*Enerkem (Canada)*		X	X	X				X		
		Hydrotreating	*Neste*					X			X	X	X
		Fast pyrolysis	*BTG-BTL*		X	X					X	X	X
Advanced		*Thermocatalytic upgrading*	*IH2, previously KIOR*		X	X	X		X	X	X	X	X
	Drop-in fuels	*Gasification followed by FT process Bio Energy*	*Red Rock, Fulcrum*		X	X	X				X	X	X
		Hydrothermal liquefaction catalytic	*Sapphire Statkraft*						X	X	X	X	X
		Supercritical water	*Licella*		X	X	X		X	X	X	X	X
		Alcohol to jet fuel	*Gevo, Byogy*	X									X

Commercial scale production

Globally, economic viability is the major barrier to advanced biofuels meeting the 2DS biofuel objectives. The current high capital costs involved in manufacturing means they still require significant financial support.

The thriving Californian biofuel industry, which receives incentives from the US Government's Renewable Fuel Standard and the California State Government Low Carbon Fuel Standard, exemplifies the benefits this support can have.

Although the vast majority of global biofuel plants produce conventional biofuels, a number of commercial-scale facilities are manufacturing advanced biofuels, and more are under construction. See Figure 6.

Figure 6 Commercial-scale advanced biofuel plants: GHD analysis

PRODUCER	PRODUCTION VOLUME P/A	PLANT LOCATIONS	FUEL AND TECHNOLOGY	STATUS
Neste	2,720 ML from vegetable oils and fats	Finland, Netherlands Singapore	Renewable diesel via hydrotreating	Operational
Renewable Energy Group	283 ML from vegetable oils and fats	USA	Renewable diesel via hydrotreating	Operational
Eni S.p.A.	360 000 tons from vegetable oils and fats	Italy	Renewable diesel via hydrotreating	Operational
Diamond Green	1,039 ML from vegetable oils and fats	USA	Renewable diesel via hydrotreating	Operational
AltAir Paramount	159 ML from vegetable oils and fats	USA	Hydrotreating isomerisation	Operational
POET-DSM	80 ML from corn stover	USA	Cellulosic ethanol via fermentation	Operational
Raízen	8 ML from bagasse	Brazil	Cellulosic ethanol via fermentation	Operational
Bolt-on additions at various corn ethanol plants	2–6 ML from corn fibre	USA	Cellulosic ethanol via fermentation	Operational
Enerkem	38 ML from MSW	Canada	Methanol and ethanol via gasification and catalysis	Under construction
Fulcrum BioEnergy	40 ML from MSW	USA	Diesel, jet fuel and naphtha via gasification and FT process	Under construction
Red Rock Biofuels	60 ML from biomass	USA	Diesel, jet fuel and naphtha via gasification and FT process	Under construction
Aemetis	160 ML from agricultural wood waste	USA	Gasification and fermentation (LanzaTech)	Under construction

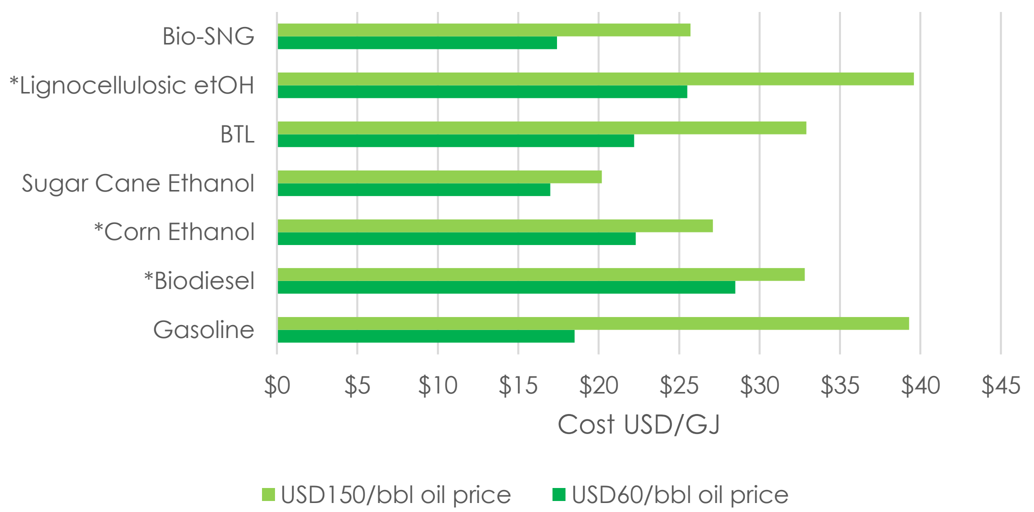
The challenge of cost competitiveness

Biofuels are a key element in reducing emissions in Australia's transport sector. But the development of a biofuel industry is hindered by the cost competitiveness of petroleum counterparts. Globally, policy driven incentives based on biofuel's demonstrated developmental and environmental benefits are encouraging the industry's growth.

Figure 7 compares the cost of gasoline with the estimated cost of technologically mature biofuel production.[12] The analysis indicates that a range of advanced biofuels could become cost competitive with petroleum-based fuels in the future, even in the absence of carbon pricing. Early policies supporting renewable power generation technologies like wind and solar photovoltaic power drove these initially higher-cost technologies to the point of parity with fossil fuels. Similarly, policies supporting biofuels are likely to increase their cost competitiveness.

Conventional corn-based ethanol manufacturing has dropped in cost and carbon intensity as petroleum fuels have increased in cost and carbon intensity, due to the growing difficulty of oil recovery and refining associated with non-conventional oil resources.

Figure 7 Estimates of biofuel production costs (*net of by-product revenues) using future mature technology.



[12] Cazzola, P., Morrison, G., Kaneko, H., Cuenot, F., Ghandi, A., and L.Fulton (2013), Production Costs of Alternative Transportation Fuels – Influence of Crude Oil Price and Technology Maturity.

Australia's opportunity gap

Australia's bioethanol production capacity is currently 440 megalitres per year (0.48 per cent of global bioethanol production).[13] Its capacity for biodiesel production sits at 100 megalitres per year (0.17 per cent of the global output).

The annual production of these two biofuels have an equivalent amount of energy as 375 megalitres of diesel. Currently, domestic biodiesel production is approximately one per cent of total domestic diesel consumption, indicating biofuel's extremely small market share. In addition, there is currently no aviation biofuel production in Australia.

The Australian car fleet is capable of using significant volumes of biofuel. As of 2015, 95 per cent of the 2.5 million cars in Queensland alone were estimated to be ethanol-compatible. This figure is likely to reach 98 per cent in 2020. Most automakers now manufacture cars suitable for higher-ethanol fuel blends. Australian plants can currently only produce enough biofuel to satisfy 0.6 per cent of the nation's demand for transport fuel, which is well behind the global average of 2.7 per cent. This capacity has decreased in the past 10 to 15 years due to plant closures. Meanwhile, existing plants are operating below full capacity.

Brazil's car manufacturers have also demonstrated the industry's ability to develop engines capable of running on high-biofuel blends. Brazil now has more than 25 million 'flex' vehicles, capable of running on zero to 100 per cent ethanol. There is a growing domestic awareness of Australia's lagging biofuel production relative to the global average, and of the benefits and opportunities increased production would bring to the broader community.

This awareness is resulting in state government initiatives like the Advance Queensland Biofutures 10-Year Roadmap and Action Plan, and the Bioenergy Roadmap for South Australia. A 40-fold expansion over the next 30 years is a significant challenge for the industry. Achieving it will require sustainable growth in feedstock resources, the application of new technologies and a consistent development of new production facilities. The investment required by production facilities alone is estimated at between $25 billion and $30 billion.

These challenges must be seen in context. Australia has large areas of arable and semi-arable land; established agricultural, forestry and engineering industries; significant feedstocks; and excellent solar resources. All of these give Australia a unique opportunity to meet its projected biofuel requirements.

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[13] 1 megalitre (ML) is equivalent to 1 million litres

Although small, the Australian biofue industry has extensive experience using low-value waste streams to remain viable in periods of policy uncertainty and low consumer demand. But it is hampered by high costs, immature technology, its small scale and the lack of a suitable policy and regulatory framework.

Figure 8 outlines the commercial biofuel plants operating in Australia, including production capacity. Notably, a number of biodiesel plants built in the early 2000s are no longer operating. Their closure is the result of several factors, including lower-cost imports monopolising the Cleaner Fuels Grant Scheme, increasing feedstock prices and inconsistent product quality.

Figure 8 Operating commercial-scale plants in Australia

COMPANY	LOCATION	FEEDSTOCK	PRODUCTION
Manildra Group	Bomaderry, NSW	Waste starch	300 ML/yr bioethanol
United Petroleum	Dalby, Qld	Red sorghum	80 ML/yr bioethanol
Wilmar Sucrogen	Sarina, Qld	Sugarcane	60 ML/yr bioethanol
Just Biodiesel	Barnawartha, Vic	Vegetable oil, tallow, cooking oil	50 ML/yr biodiesel
Eco Tech Biodiesel	Narangba, Qld	Cooking oil, tallow	30 ML/yr biodiesel
Biodiesel Industries Australia	Maitland, NSW	Cooking oil, vegetable oil	20 ML/yr biodiesel

Australian technology delivering internationally

Australia does not currently have any commercial facilities for manufacturing advanced biofuels operational or under construction. However, a number of advanced biofuel technologies are being demonstrated in Australia, and some Australian technologies are currently being deployed overseas. These include:

1. **Catalytic hydrothermal processing** developed by Licella. In Canada, Canfor is using the technology to convert sawdust and timber mill waste into liquid biofuels
2. **Leaf Resources' Glycell process**, which efficiently breaks down lignocellulosic biomass into C5 and C6 sugars, and is undergoing a feasibility investigation in Malaysia
3. **Hydrothermal liquefaction technology**, which Muradel demonstrated in Whyalla, South Australia; The Northern Oil Refinery in Gladstone, Queensland is implemented a demonstration-scale variant of the technology
4. **Ethtec cellulosic ethanol technology**, which has been piloted in a plant in northern NSW, and which is being upscaled in NSW's Hunter Valley.

The relatively small number of global commercial facilities manufacturing advanced biofuels reflects the financial challenges of deployment and the infancy of the technology.

Hundreds of conventional ethanol and biodiesel facilities operate around the world. The majority belong to manufacturers of corn-based ethanol in the US; sugarcane-based ethanol in Brazil; wheat- and sugar beet–based ethanol in Europe; and biodiesel manufacturers in the US, Europe and Asia.

Recent developments have made it possible to produce advanced biofuels at conventional plants. Bolt-on technologies can produce cellulosic ethanol from corn fibre, and extract corn oil for diesel production via hydrotreating. These developments, along with increased operating efficiencies and alternative energy sources, have led to substantial improvements in the carbon dioxide balance of conventional biofuels.

In the Australian context, future biofuel developments should focus on sustainable, low carbon, advanced biofuel technology. Co-located conventional and advanced facilities, combining financial returns with sustainability, could be the model for a way forward. These facilities could be based on biorefinery systems that make full use of the whole sugarcane plant to produce food products, conventional ethanol, cellulosic ethanol, and renewable heating, cooling and power.

Framing a domestic development pathway

Given the decarbonisation challenge facing the transport sector, it is timely for Australia to consider long-term policies that could accelerate the growth of the biofuel industry and encourage investor confidence.

Australia does not have a strong history of policy interventions to support biofuels compared with other nations. Biofuel blend mandates in NSW and Queensland have provided some demand for biofuels. At the national level, the biofuels sector benefited from the Ethanol Production Grants Program and the Cleaner Fuel Grants Scheme. Until 2015, these provided a full excise rebate on domestically produced ethanol, and biodiesel produced in or imported into Australia. However, the Diesel Fuel Tax Rebate – which applied only to fossil fuel-derived fuels – limited the impact of these policies on the biofuel industry.

Countries including the US, Brazil and European Union member nations have developed policies in line with the prevailing view that biofuels are an effective instrument for decarbonising the transport sector, increasing national fuel security, strengthening regional agricultural development and employment, and creating resilience.

The impact of strong biofuel policies is clear in the US, with its national Renewable Fuel Standard scheme and California's Low Carbon Fuel Standard. These policies, which provide financial incentives based on biofuel carbon credentials, have driven development and investment into conventional and advanced biofuels. In fact, Australian tallow is converted into renewable diesel at the NexBTL refinery in Singapore, to be sold in the Californian market. Similarly, the majority of Australian canola seed – considered a low-carbon feedstock due to Australian farming methods – is exported to Europe for conversion to biodiesel.

Although using Australian feedstocks to meet overseas biofuel mandates raises questions about sustainability and market distortions, it clearly demonstrates how policy works as the fundamental driver for nascent industries like biofuels.

Beyond domestic borders, international transport industry policies are providing opportunities for biofuels by creating emission mitigation polices and targets:

- In June 2018, the International Civil Aviation Organization (ICAO) established a set of international standards for its Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). This plan aims to stabilise carbon dioxide emissions from international aviation from 2020 onward.
- In April 2018, the International Maritime Organization agreed to reduce the global shipping industry's annual greenhouse gas emissions by at least 50 per cent compared to 2008 levels, by 2050.

Global experience has resulted in mature policies and standard initiatives that provide clear guidelines for achieving sustainable outcomes. Some international initiatives Australia could replicate, and that investors should be aware of, include:

- setting production volume targets for renewable fuel (specific to advanced biofuels in some cases)
- developing key performance indicators for technology maturity and risks
- providing funding in proportion to emissions reduction potential, calculated in a standard greenhouse gas lifecycle analysis framework
- ensuring feedstocks are not produced on land with high biodiversity value, and guaranteeing a verifiable custody chain from feedstock to fuel
- developing indicators for assessing and monitoring biofuel sustainability.

The Australian advantage

Multiple biofuel feedstocks and technologies

Australia's existing skills and experience in agriculture, forestry and engineering give us the tools to develop a thriving biofuel industry. To build an industry at the required scale, Australia needs early investment in construction of 'first-of-their-kind' facilities. This investment will also ensure training and skills development occur locally instead of being outsourced.

Multiple biofuel feedstocks and technologies are required if Australia is to achieve the volume of biofuel production required under the 2DS. Australia could hasten its journey towards the 2DS target by:

- converting a greater volume of transport fuels' underutilised waste streams into biofuels
- converting Municipal Solid Waste into biofuels in key urban and regional centres
- establishing a number of medium-scale hydrotreatment facilities in Australia for producing jet fuel and biodiesel, using existing tallow, cooking oil, trap grease resources, and purpose-grown vegetable oils like carinata, camelina, mustard and pongamia
- developing conventional biofuel plants as co-production bases as part of the transition to advanced biofuels
- transforming bio-based timber and paper plants into biorefineries.

The existence of functioning supply chains in these examples mean the costs and risks of feedstock supply would be relatively low.

The Iowa POET-DSM cellulosic ethanol facility's production of commercial volumes of fuel and the Canadian Enerkem facility's conversion of MSW into methanol and ethanol both indicate the dawn of a new era in biofuel production.

These developments will result in growing investor confidence in biofuel technologies. Additional technologies like Aemetis, LanzaTech, Fulcrum BioEnergy and Red Rock Biofuels, to name a few, could be commercially proven by 2020. Already, renewable diesel facilities across the globe have proven commercially viable, where markets support low-carbon fuels. The field is continually expanding.

As these technologies move down the cost curve and towards technical maturity, early-stage investors could build confidence with private investors and help promote the advanced biofuels industry.

Industry development

Legislation supporting minimum volumes of biofuel per unit of fuel – or mandating its inclusion in fuel blends – is driving global biofuel uptake rates. At the same time, the diversity of potential feedstocks, processing technologies and end-use requirements is setting the biofuel industry on a steep learning curve.

Ongoing investment is expected to reduce costs for the biofuel

industry. Technological development and scaling – not to mention the learning and development associated with cumulated installed capacities and operating hours – are also putting downward pressure on production costs.

Technological development

More broadly, the biofuels industry could benefit from technical development and investment support for projects that:

- increase the volume of base feed stocks for renewable diesel, jet fuel and biodiesel production
- address issues associated with advanced biofuels processing, such as oil upgrading
- incorporate biofuel product certification and knowledge-sharing processes
- inform policy and regulatory considerations about external factors that could support a strong domestic biofuel industry.

Technology gains

Potential beneficiaries of developmental support could benefit:

- technologies and projects that increase the volumes of vegetable oil and fats in renewable diesel, jet fuel and biodiesel production. This could include options for new crops such as Carinata and microalgae; incremental changes to existing crops like NxtOil; or recovering oil from current waste streams, as the US does with corn oil
- technologies that recover bio-CNG from currently underutilised waste streams
- technologies that address particular problems in advanced biofuel processes, including: in situ or post-pyrolysis and post-hydrothermal liquefaction oil upgrading, to reduce oxygen content and improve quality
- techniques for cost reduction and increased reliability in the pre-treatment of advanced ethanol
- gasification and FT technologies at a suitable scale for Australian biomass resources.

Investment considerations

Biofuel projects and companies can offer an attractive investment opportunity. The investment required by production facilities alone in Australia is estimated at between $25 billion and $30 billion.

The current global trend in policy and market forces is to favour low carbon biofuels. This has placed a ceiling on conventional biofuels production, due to its limited capacity to achieve the required carbon reductions.

This trend does not rule out the possibility of supporting conventional biofuel plants. However, conventional plants need to consider:

1. developing commercial resilience, which they can gain by either joining an integrated plant (such as one producing sugar, power and ethanol) or by being capable of transitioning to advanced fuels. This would involve following the overseas examples of conventional processors that have gained the industry know-how to develop new advanced fuels
2. navigating the real risk of a plant becoming redundant well before it reaches the end of its life, due to new advanced biofuel developments
3. submitting an independent, peer-reviewed Life Cycle Assessment, to demonstrate their sustainability
4. avoiding displacing existing domestic capacity, and become internationally viable
5. proving that they would not hinder the development of the broader biofuel industry in the case of poor performance
6. avoiding impairing the development of advanced biofuels by monopolising long-term market opportunities through long-term contracts.

Benefits beyond biofuels

The main environmental benefit of biofuel development is decarbonisation of the transport sector. However, the use and production of biofuels bring broader socioeconomic and environmental benefits.

Both conventional and advanced biofuels generally lead to significant reductions of exhaust contaminants (sulphur dioxide, nitrogen oxide and particulate matter), resulting in improved air quality. Biofuel production can contribute to land restoration by providing an economic impetus for rejuvenating degraded or marginalised land, especially through the cultivation of woody and perennial crops.

The biofuel industry can contribute to a circular economy by recycling waste streams that are currently sent to landfill or burned – such as biosolids, agricultural residues and forest thinnings. This process also offers a potential to co-produce biochar for soil restoration.

The desire for fuel supply stability and the diversification of agricultural products pushed Brazil to develop its 20-gigalitre sugarcane ethanol industry. By expanding its products, the sugarcane industry was able to stay financially secure in periods of low sugar pricing. Fuel security and price controls meant the supply of fuel remained stable in times of high oil pricing and international strife.

In Europe, decarbonisation and national security have acted as the major drivers of the biofuel industry. These diverse drivers explain why conventional biofuels may have been developed without thought for some of the broader environmental challenges biofuels now face.

The biofuels of choice in the US and Brazil were not necessarily the best environmental options, but they were the most costeffective means of providing fuel security and regional economic development.

The experience other countries have gained in the biofuel field gives Australia a unique opportunity to develop an industry primarily driven by environmental factors, while also achieving the substantial socioeconomic and geopolitical benefits our predecessors gained from their own biofuel industries.

Investment in biofuels needs to be seen as an investment not just in technology but in an entire industry. Like any industrial investment, it will bring broader socioeconomic benefits. This may be most evident in regional areas, where biofuel production can support regional industrial development and job creation. The development and job opportunities created by distributed biofuel industries – or by large biorefineries in areas with abundant feedstocks – could help create resilient communities by diversifying income and improving both local and national fuel security. Global employment figures suggest that an Australian biofuel production target of 20 gigalitres could provide ongoing employment for up to 250,000 people.[14]

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[14] Based on Australian production of 20 billion litres per year; 1.7 million people globally employed in biofuels (ARENA (2017), Annual Review, Renewable Energy and Jobs); and global biofuel production of approximately 140 billion litres per year (IEA (2017), Energy Technology Perspectives, Tracking Clean Energy Progress 2017).

There is a significant opportunity to develop and export technology related to biofuels, as the examples of Australian firms Licella and Leaf Resources already demonstrate.

Local production will also likely improve Australia's trade balance and potentially provide export opportunities for countries lacking the same natural resources as Australia.

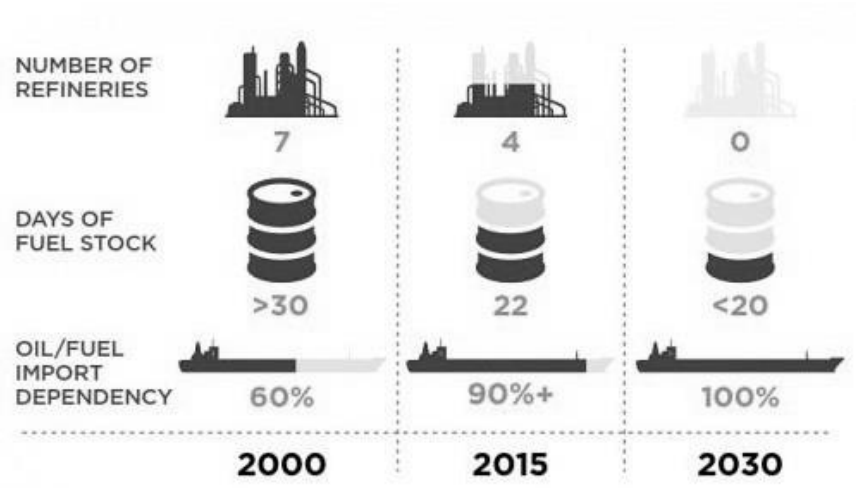
The quest for fuel security has been a fundamental driver of biofuel-friendly policies in the US and Brazil. Figure 9 shows Australia's increasing dependence on imported oil and transport fuels. A biofuel industry will lessen this dependence, which in turn will reduce the risk of supply restraints during times of international or regional geopolitical upheaval. The self-reliance engendered by domestic biofuel production could assist Australia's commitment to fuel supply security.[15]

With a strong local biofuel industry, international oil prices would have reduced impact on Australian fuel prices, giving Australia a degree of resilience when oil prices peak, and reducing our risk of engaging in oil-for-trade-influence deals.

A domestic biofuel industry would also benefit Australia by easing the burden of oil storage. With the closure of major refineries and limited investment in fuel storage, our small stores – combined with our 90 per cent dependence on foreign crude and refined fuel imports – create a significant risk that biofuels could effectively mitigate.

The non-environmental benefits of domestic biofuel production have been demonstrated repeatedly across the globe. Historically, these benefits have been the main impetus for large-scale biofuel development. A domestic biofuel industry would generate environmental dividends and bring socioeconomic benefits to the whole Australian community.

Figure 9 Examples of Australia's increasing dependence on fuel imports.[16]



[15] NRMA Motoring and Services (2013), Australia's Liquid Fuel Security: A Report for NRMA Motoring and Services.

[16] NRMA Motoring and Services (2013), Australia's Liquid Fuel Security: A Report for NRMA Motoring and Services.

About this report

The Clean Energy Finance Corporation (CEFC) and the Australian Renewable Energy Agency (ARENA) sought analysis from GHD about the global and Australian biofuels sectors, including the challenges and opportunities for the further development of the Australian biofuel industry.

GHD considered the magnitude of the challenge to develop a thriving biofuel industry in Australia, including sustainability constraints. It assessed the level of Australian biofuel production consistent with a global transport carbon reduction strategy and considered how biofuels can complement other technologies in the transport sector in particular.

In addition, the report canvassed the potential development of an Australian biofuel industry, outlining policies that have been central to the successful development of the sector in other markets. The economic challenges and broader societal benefits of biofuels relative to fossil fuels were also explored.

This document provides an overview of the main findings.

Disclaimer

The *Biofuels and Transport: An Australian Opportunity* is based on a full report prepared by GHD Pty Ltd (Report) for the Clean Energy Finance Corporation (CEFC) and the Australian Renewable Energy Agency (ARENA), specifically for the purpose agreed between GHD, CEFC and ARENA as set out in the Report. It is not intended for use for any other purpose.

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About the CEFC

The CEFC has a unique role to increase investment in Australia's transition to lower emissions. We invest to lead the market, operating with commercial rigour to address some of Australia's toughest emissions challenges - in agriculture, energy generation and storage, infrastructure, property, transport and waste. We're also proud to back Australia's cleantech entrepreneurs through the Clean Energy Innovation Fund. In investing $10 billion on behalf of the Australian Government, we work to deliver a positive return for taxpayers across our portfolio.

About ARENA

ARENA's purpose is to accelerate Australia's shift to affordable and reliable renewable energy. ARENA was established on 1 July 2012 by the Australian Renewable Energy Agency Act 2011. ARENA operates at the leading edge of new energy solutions where both risk and potential reward are high. ARENA aims to bring about transformational change by supporting innovation in energy products, services and business models. To achieve this, ARENA provides grant funding to projects, shares knowledge and collaborates across the energy sector.