The Potential Role of Drop-in, Zero-Carbon Fuels

Power Session Webinar

20 June 2023

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Agenda

- Introduction
- Voting on future power sessions topics
- Format including Q&A
- Australia net zero targets and key strategies
- Australia's drop-in biofuel alternative
- California case study
- Concluding remarks
- Next Power Session
- Q&A

Australia's CO2 Targets and Strategies

Reduction Trends

Reduction Targets

Reduction Strategy

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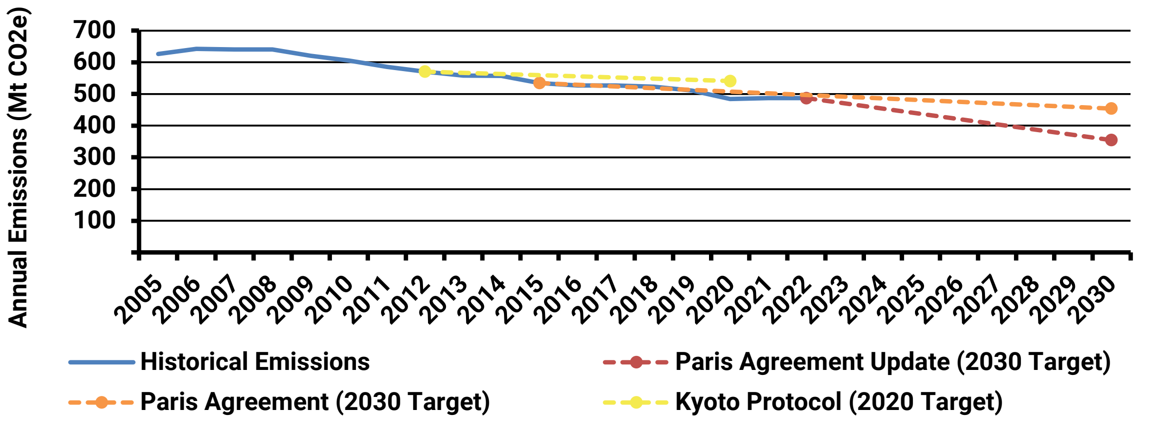
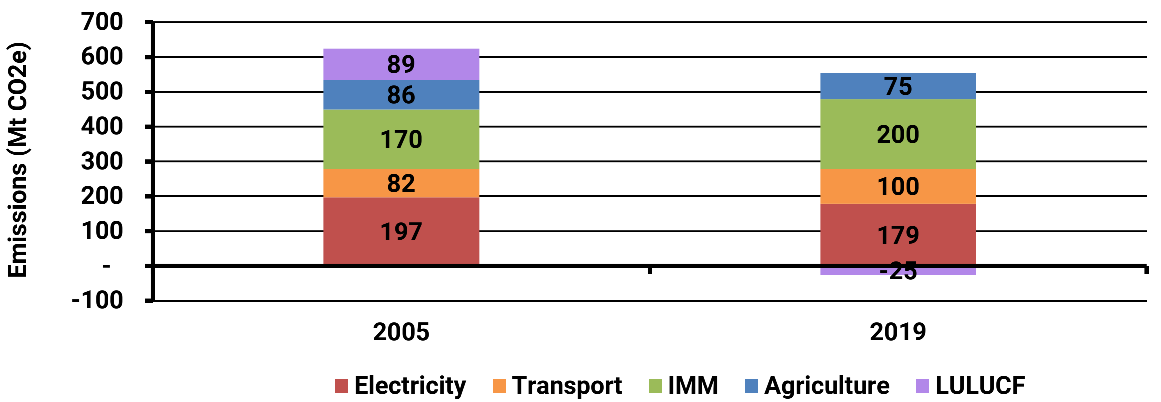
Australian Emissions Abatement to Date

Annual Historic CO2e Emissions



Note: Target trajectories are shown from the year the target was set to the target year
Source: DISER (2022), Energeia

Change in Emissions by Sector (2005-19)



IMM: Industry, Mining and Manufacturing
LULUCF: Land Use, Land Use Change and Forestry
Source: DCCEEW (2021)

- Australia has reduced its emissions by 1.6% per year on average over the past decade, even as global emissions have increased 1.8% per year
- Australia has reduced emissions by 20% from 2005 to 2019 with emissions per person falling by 36%
  - Australia's farmers and regional communities changed land management practices, mainly reductions in primary forest clearing
  - Electricity sector emissions fell as large-scale renewables, rooftop solar and energy efficient technologies have been adopted
  - Total emissions from industry, mining and manufacturing (IMM) have risen due to a lack of cost effective emission reduction options
  - Low transport electrification and an increase in the number of ICE vehicles caused transport emissions to rise from 2005 to 2019
- Australia has beat its Kyoto Protocol target for 2020, and was on track for its original Paris Agreement target for 2030 – the new target will be more challenging

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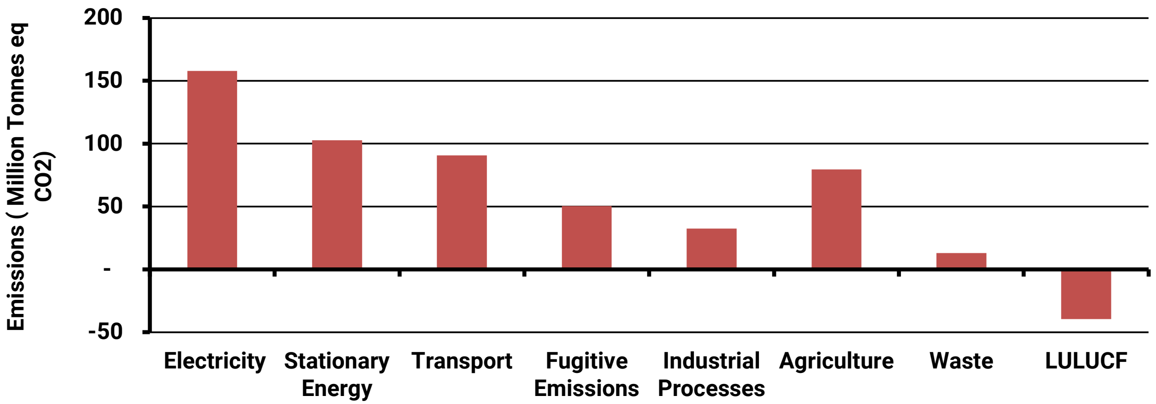
Australia's Federal and State CO2 Targets

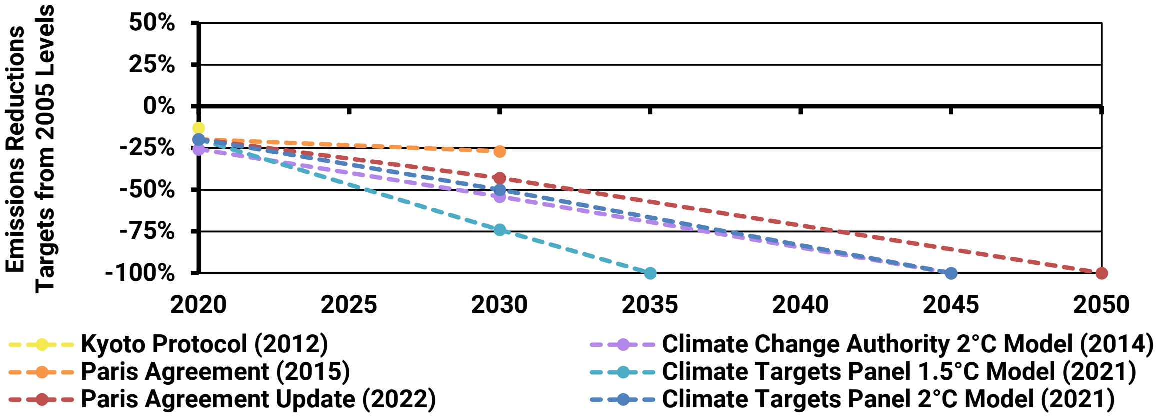
Current Emissions by Sector (2022)



LULUCF: Emissions offsets from the Land Use, Land Use Change and Forestry
Source: DCCEEW (2021), Energeia

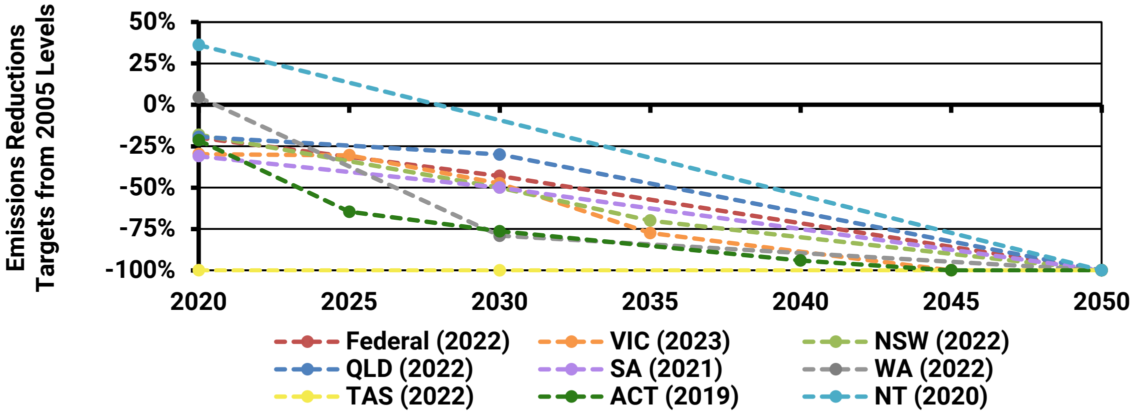
- Electricity generation is still the leading sector for emissions contributions
- Electricity, stationary energy, and transport, including fugitive emissions (from pipelines, appliances, etc.), account for 82% of Australia's current emissions
- Australia has committed to increasingly ambitious reduction targets but under-deliver on the 2°C Paris Agreement according to Australian and independent international climate models
  - Therefore, additional tightening is possible, if the cost and risks expected by policymakers are manageable
- State government targets vary significantly across Australia. However, **only ACT and VIC currently committed to a 2045 target**
  - Energeia expects more to follow suit in the coming years
- The Climate Targets Panel consists of experienced Australian climate scientists, and policymakers focused on leading informed discussions on emissions targets

Historic and Current Targets vs. Required Reduction Models



Note: 2020 datapoint is historical (excluding the Kyoto Protocol and Climate Council Authority targets)
Source: DCCEEW (2021), Climate Targets Panel (2021), Climate Change Authority (2014), Energeia

Federal and State Net Emissions Reduction Targets



Note: 2020 datapoint is historical, TAS has already exceeded net zero target and are net negative
Source: DCCEEW (2021), State Governments, Energeia

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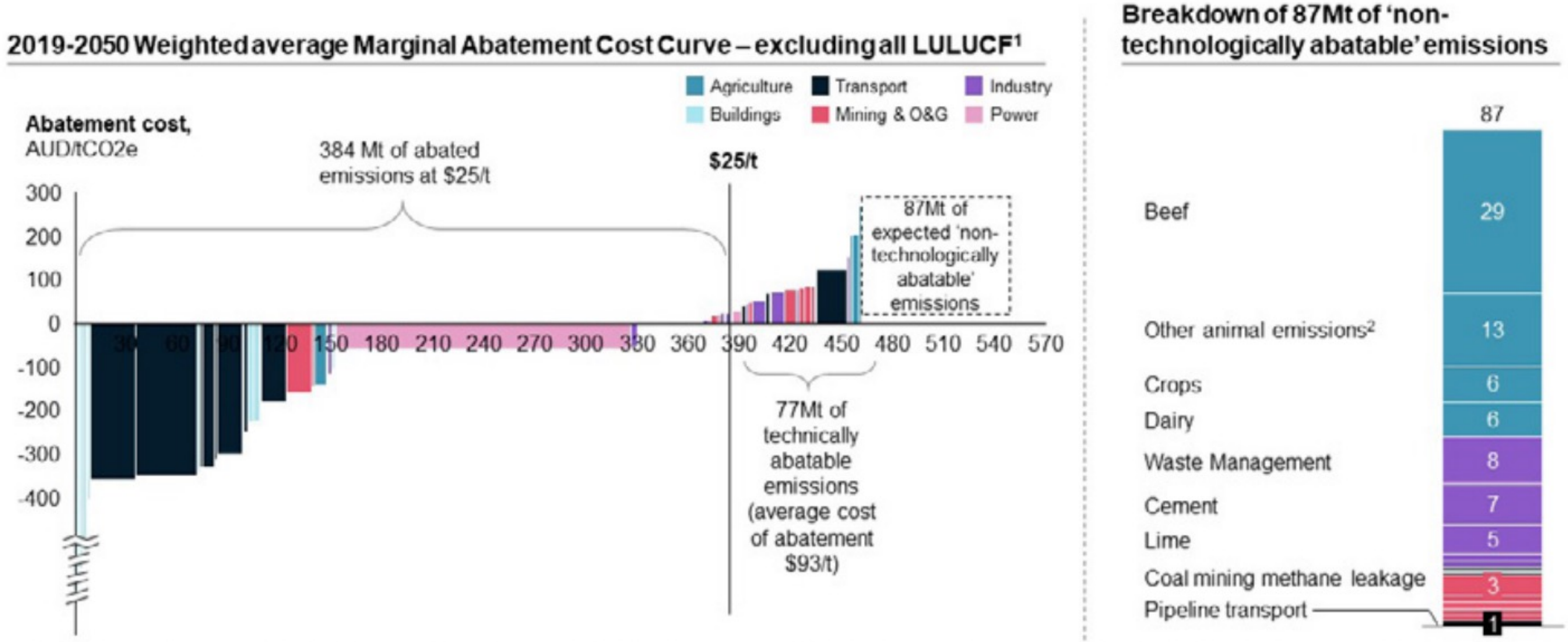
Australia's Emissions Abatement Supply Cost Curve (2021)



1. Note ~549Mt total emissions shown, approx. 4m tons higher than the 2019 baseline (excluding LULUCF), as the abatement is calculated on a 2050 BAU scenario where changes in exports and consumption change the reduction needed
2. Other animal emissions estimated to be >80% attributable to sheep

Source: DCCEEW (2021) , McKinsey (2021)

- Transport accounts for the majority of negative cost (lifecycle, end of life basis) opportunities, followed by power
  - Interestingly, transport and power abatement shown as lower cost than oil and gas
- Opportunities with costs greater than $93/t CO2e considered 'not-technologically abatable'
  - Agriculture, industry and mining account for nearly all of these emissions
  - Interestingly, many of these emissions potentially addressable by drop-in biofuels%

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Key Tech Assumptions in Australia's Emissions Reduction Plan (2021)

Technology	Industry	Expected Timing of Cost Parity	Technology Methods	Government Action
Clean Hydrogen	Transport, Mining and Manufacturing	Production to reach under $2/kg (2025-2030)	• Steam methane reforming with CCS • Renewable electrolysis	• Build intl. supply chains and advance R&D • Develop domestic Hydrogen Guarantee of Origin scheme • Support development of CCS and CCUS projects • Foster innovation, collaboration and knowledge sharing
Ultra Low-cost Solar	Energy-Electricity Generation	Generation cost will reach at $15/MWh (2025-2035)	• Develop module efficiency from ~22% to 30% • Reduce balance of plant costs by ~70%	• Invest in grid-scale and rooftop solar • Advantage solar for supplying clean electricity
Energy Storage for Firming	Energy-Electricity Generation	Stored electricity <$100 per MWh (2025-2030)	• Lithium-ion batteries	• Increase access to capital for early-stage tech • Fund feasibility studies and demonstration projects • Support R&D to ID opportunities in the supply chain
Steel and Aluminium	Manufacturing	Low CO2 steel < $700/tonne and low CO2 aluminium production under $2,200/tonne (2030-2040)	• Renewable electricity and inert anodes for steel • Hydrogen and direct reduction of iron for aluminium	• Fund and finance low emissions materials • Decarbonise the energy used in smelting • Reduce CO2 from converting ore to metal
Carbon Capture, Utilisation and Storage	Industrial processes including natural gas processing, cement production, etc.	CO_2 compression, hub transport and storage for <$20/tonne of CO_2 (2025-2030)	• Large-scale deployment of CCUS for or hard-to-abate industries such as natural gas processing and cement.	CCUS development fund to support • Direct air capture and removal • Capture and geological storage from power stations • Capture and use of CO_2 in construction materials
Soil Carbon	Offset CO2 from hard-to-abate sectors, such as agriculture, industry and heavy transport	Soil organic carbon measurement under $3 per hectare per year (2025-2030)	• Advancement in proximal sensing, modelling and remote sensing technologies	• Incentives for landholders to improve soil carbon • Invest on Soil Carbon Data Program • Develop soil science, ag tech and soil productivity

Source: DCCEEW (2021) , McKinsey (2021)

- Hydrogen cost and availability assumptions are a key component of Australia's CO2 reduction strategy
  - Impacts low CO2 aluminium targets as well
- Soil carbon and carbon capture and CCS are also a key assumptions of Australia's current CO2 reduction strategy
- Drop-in biofuels are a potential solution to hard-to-abate sectors covered by these two strategies

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Drop-In, Zero-Carbon Fuel Comparisons

Australian Biofuel Trends

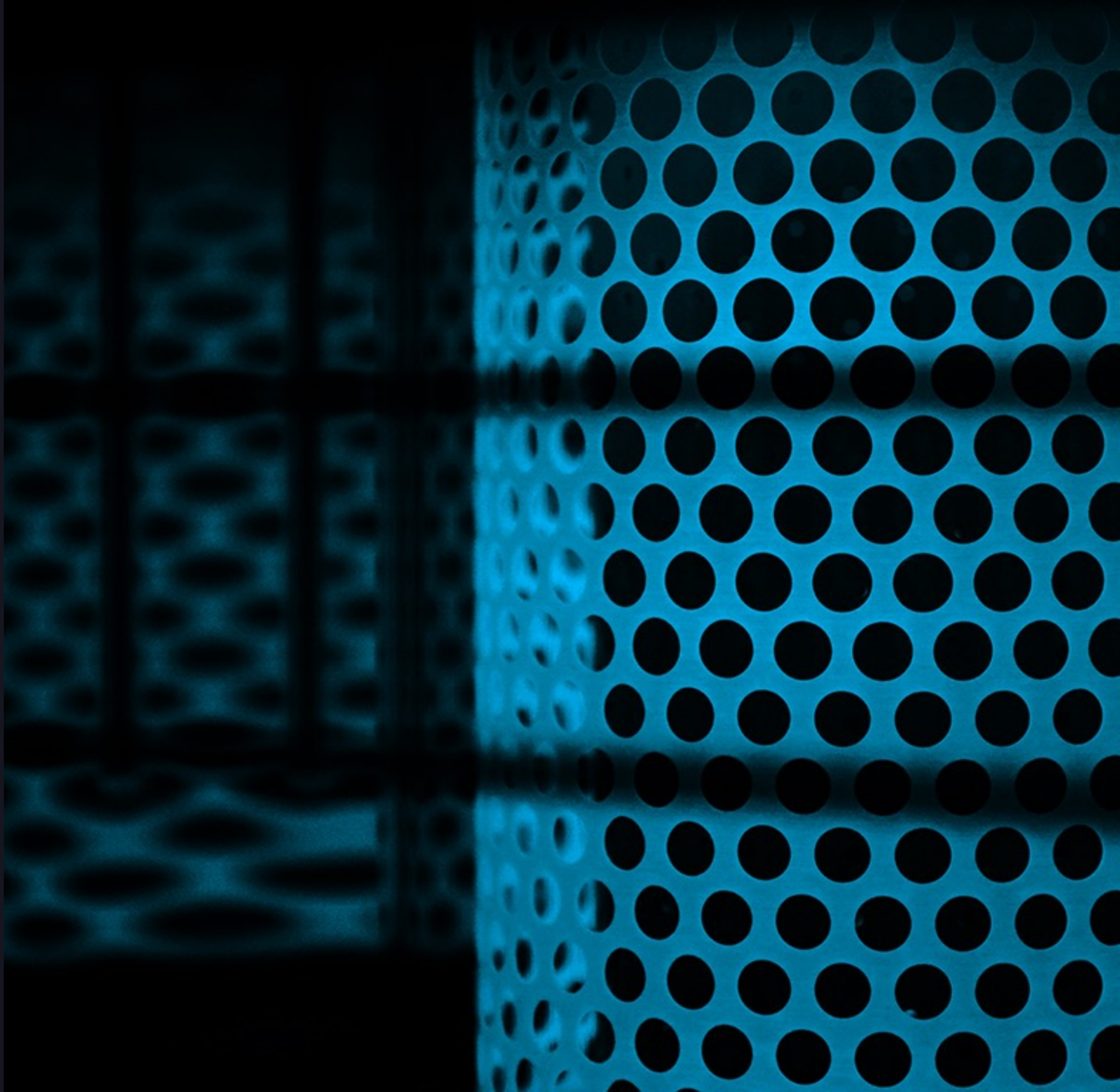
Current Role of Biofuels in Australia

Key Zero Carbon Biofuel Applications

Drop-in Biofuel Pathways

Key Zero Carbon Fuel Prices and Outlook

Drop-in Biofuel Feedstock Potential



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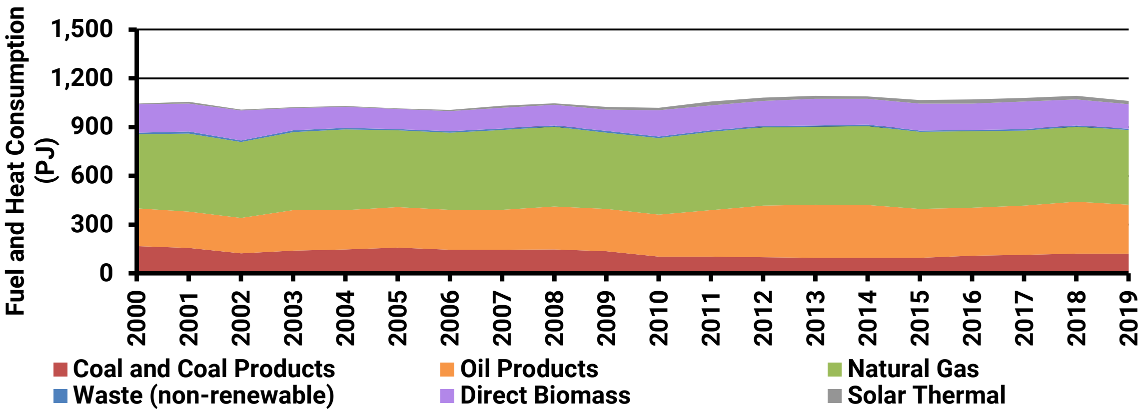
Input Energy Trends by Sector

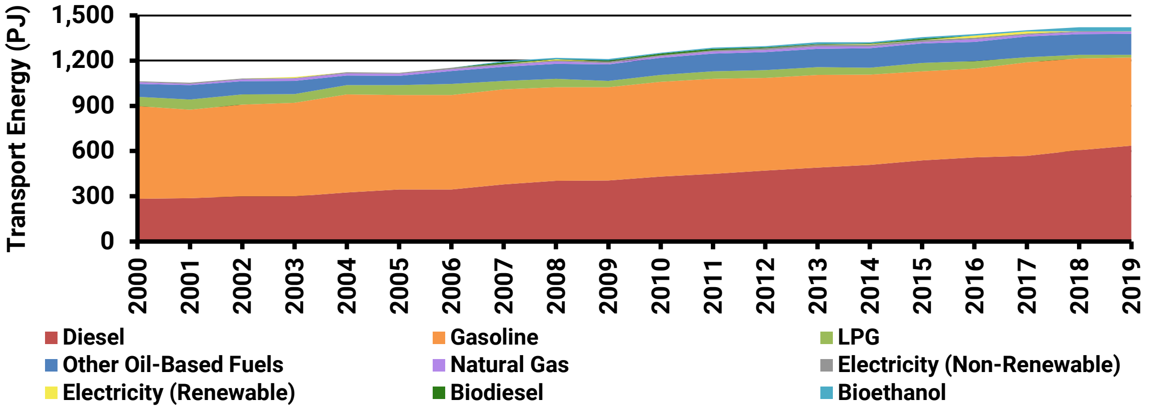
Fuel and Heat Consumption



Source: IEA (2021), Note: Heat sector includes the residential sector, commercial and public services and agriculture/forestry. Transport fuels are excluded.

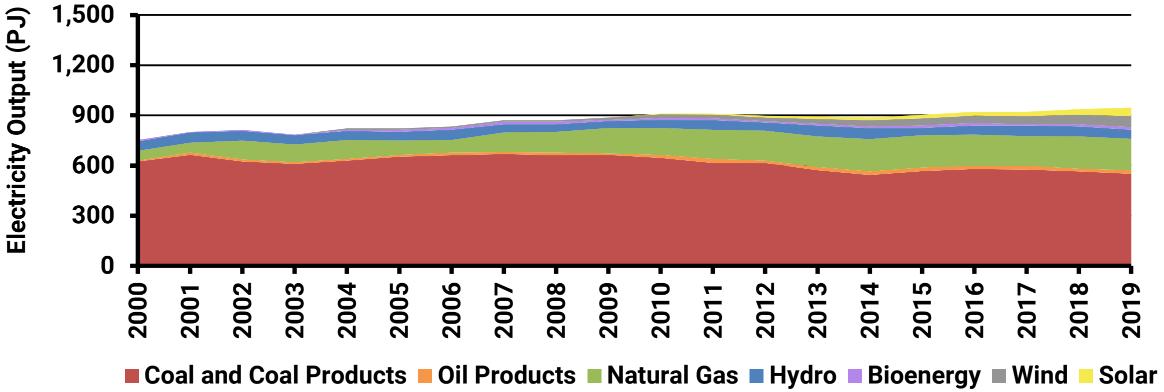
- Biofuels have represented a tiny fraction of energy input into heating, transport and electricity applications
- This is mostly driven by its relatively high cost absent any subsidisation
- NSW and QLD have biofuel mandates, but we understand that they are not binding

Transport Energy



Source: IEA (2021)

Electricity Generation



Source: IEA (2021)

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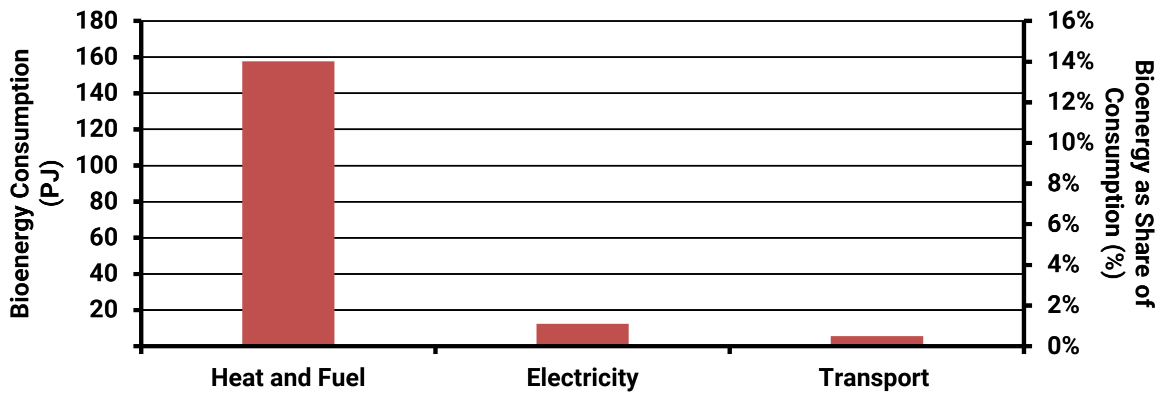
Current Role of Biofuels in Australia

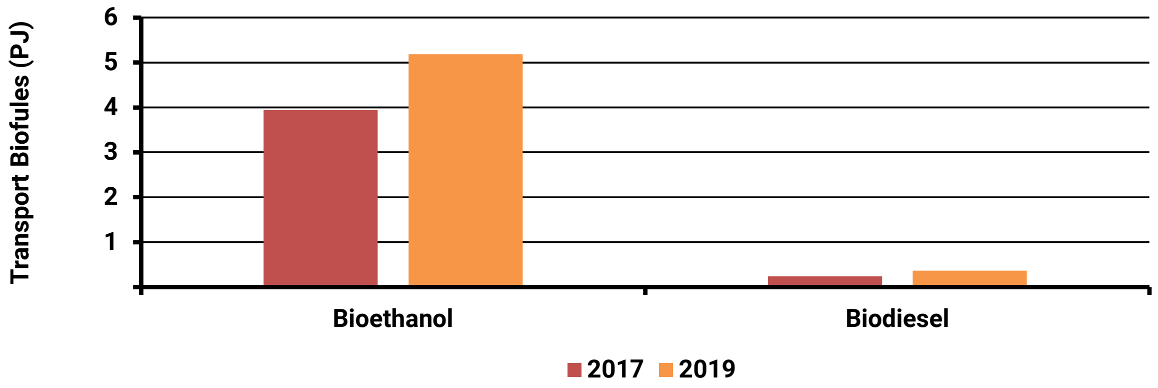
Bioenergy in Key Australian End Use Sectors (2019)



Source: IEA (2021)

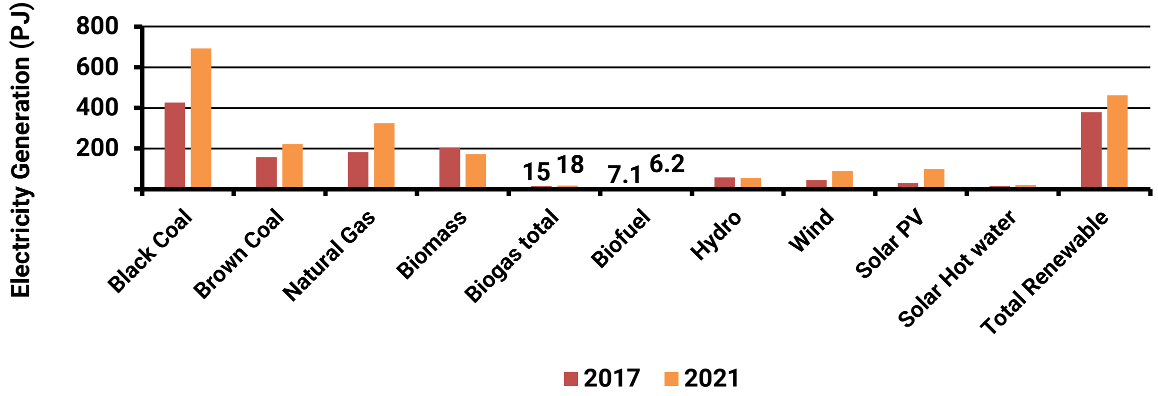
- Biomass for heating and fuel applications almost 16 times higher than next largest application
- Biofuels play a relatively minor role in Australia's electricity and transport markets
- Relatively high cost of RNG and renewable diesel and lack of support have limited their roles to date
- Potential future role a function of feedstock availability and fuel production costs

Biofuels in Transport



Source: Australia Biofuel Annual from USDA Foreign Agricultural Service (2018) and DCCEEW (2021)

Electricity Generation by Fuel Type



Source: IEA (2021)

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Key Biofuel and Hydrogen Applications

Key Biofuel Applications

Application / Fuel	Biogas	Bioethanol	Biodiesel	Renewable Gas	Renewable Diesel	Green Hydrogen
Space Heating	✓	✗	✗	✓	✗	✓
Process Heating	✓	✗	✗	✓	✗	✓
Air Transport	✗	✓ (yellow)	✓	✗	✓	✓
Marine Transport	✗	✓ (yellow)	✓	✗	✓	✓
Road Transport	✗	✓ (yellow)	✓	✓	✓	✓
Electricity Generation	✓	✗	✗	✓	✓	✓
Fertiliser Feedstock	✗	✗	✗	✓	✗	✗
Chemical Feedstock	✗	✓ (yellow)	✗	✓	✗	✓
Explosive Feedstock	✗	✗	✗	✗	✗	✓
Aluminium Feedstock	✗	✗	✗	✗	✗	✓

Source: Energeia Research, Note: ✓ = Drop-In Replacement, ✓ (yellow) = Requires Special Equipment or Processing, including blending

- Renewable Natural Gas (RNG) and Renewable Diesel are two types of biofuels with wider applicability than the most popular biofuels in Australia
- They are also a better match for green hydrogen, in terms of providing a potential alternative pathway at lower cost and risk in the near term

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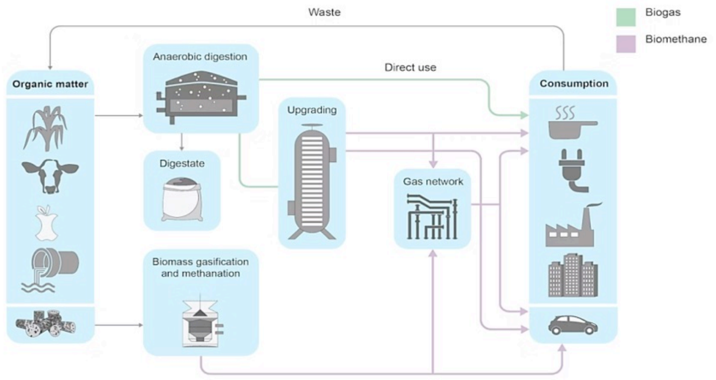
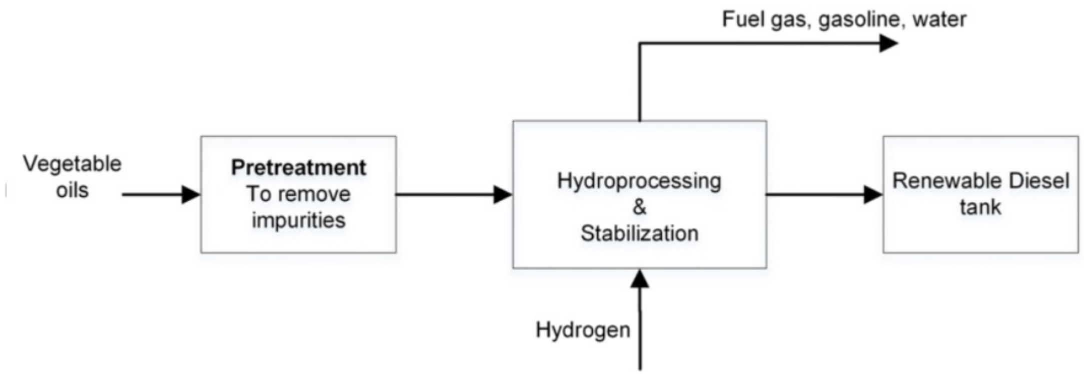
Drop-in Zero Carbon Fuel Production Pathways

Production Pathway for Renewable Natural Gas



Source: IEA

Production Pathway for Renewable Diesel



Source: Recent Developments in Commercial Process for Refining Bio-Feedstocks to Renewable Diesel, Bo Zhang, 2018

- Biomethane or Renewable Natural Gas (RNG) can be made from a wide variety of organic feedstocks
  - Each of these is a source of CO2 and other GHG (e.g. methane) emissions
  - It is an upgraded form of biogas, removing impurities to deliver pipe quality methane
- Renewable diesel is typically made from feedstock (such as vegetable oils, fats etc.) and processed via the hydrotreating pathway
  - It is an upgrade from biodiesel as it is made with hydrogen
- Several pathways can be used to generate hydrocarbon fuels such as Green Hydrogen, including
  - Gasification
  - Pyrolysis
  - Biological sugar upgrading

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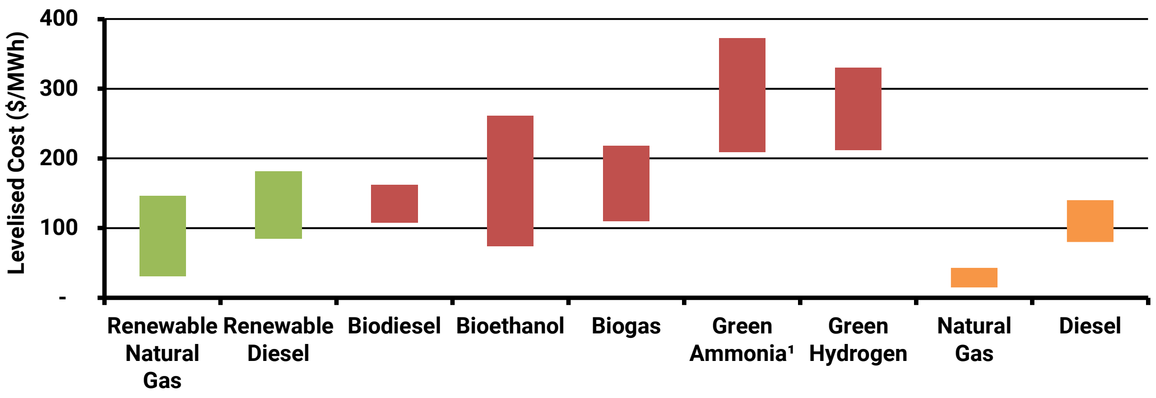
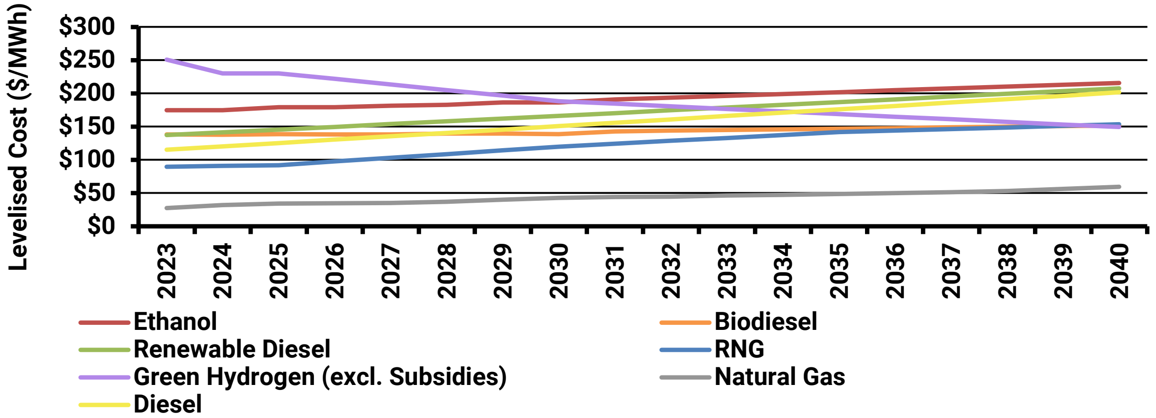
Zero Carbon Fuel Costs

Current Levelised Cost of Fuel-by-Fuel Type in Australia



Source: ARENA (2021), [1]Energeia estimate using research from CSIRO, Argus, AER
Note: Drop-in fuels are green, fossil fuels are orange

Forecast Fuel Production Costs



Source: CEFC (2021)
Note: All fuel types were forecasted forward using US price trends

- Renewable diesel and biodiesel are already approaching cost parity with carbon-sourced counterparts
- Detailed forecasts for zero carbon fuels are not widely available or specific to Australia
  - Projections shown are based on work we did in North America (detailed later in deck)
- Key questions include how much feedstock is available, and at what price?

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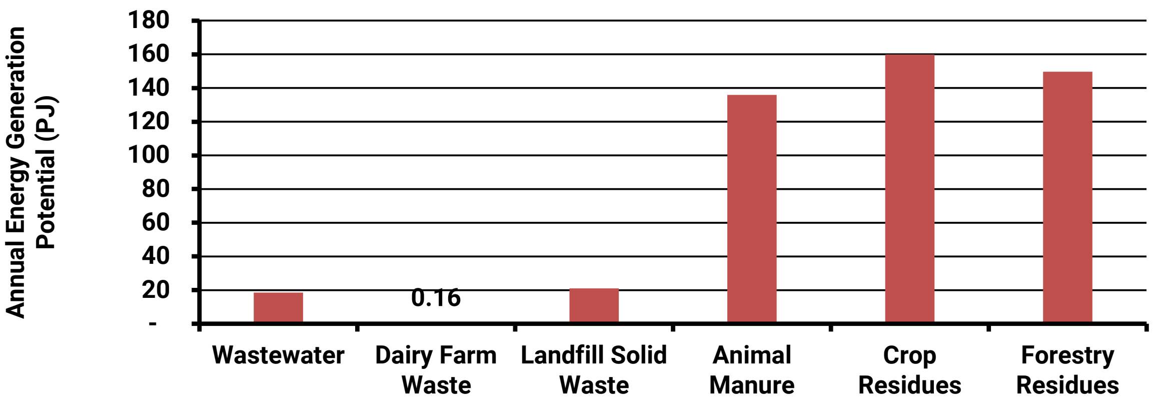
Current Feedstock Options and Production

Feedstock by Fuel Type

Feedstock		Renewable Natural Gas	Renewable Diesel	Biodiesel	Bioethanol	Biogas
Waste	Municipal Water	✓				✓
	Dairy Farm	✓				
	Landfill Solid	✓				✓
	Cooking/Vegetable Oil		✓	✓		
Residues	Forestry		✓			
	Crop	✓	✓			✓
Animal	Fats			✓		
	Manure					✓
Plant	Molasses				✓	
	Wheat				✓	
	Oil Mallee		✓			
	Sorghum				✓	

Source: Energeia Research

Current Energy Generation Potential of Zero Carbon Fuels in AU



Source: Energeia Research

- Key drop-in zero carbon biofuel feedstocks are shown in the table to the left
- The current levels of production in weight terms is given in the bottom left
- While there are significantly more energy in crop and forestry residues, they are not necessarily the lowest cost form of feedstock
- It is also worth mentioning that there can be a wide variation in the cost within a category
  - Larger locations close to infrastructure typically see the lowest unit cost outcomes
  - As these sites are developed, the marginal cost of additional capacity increases

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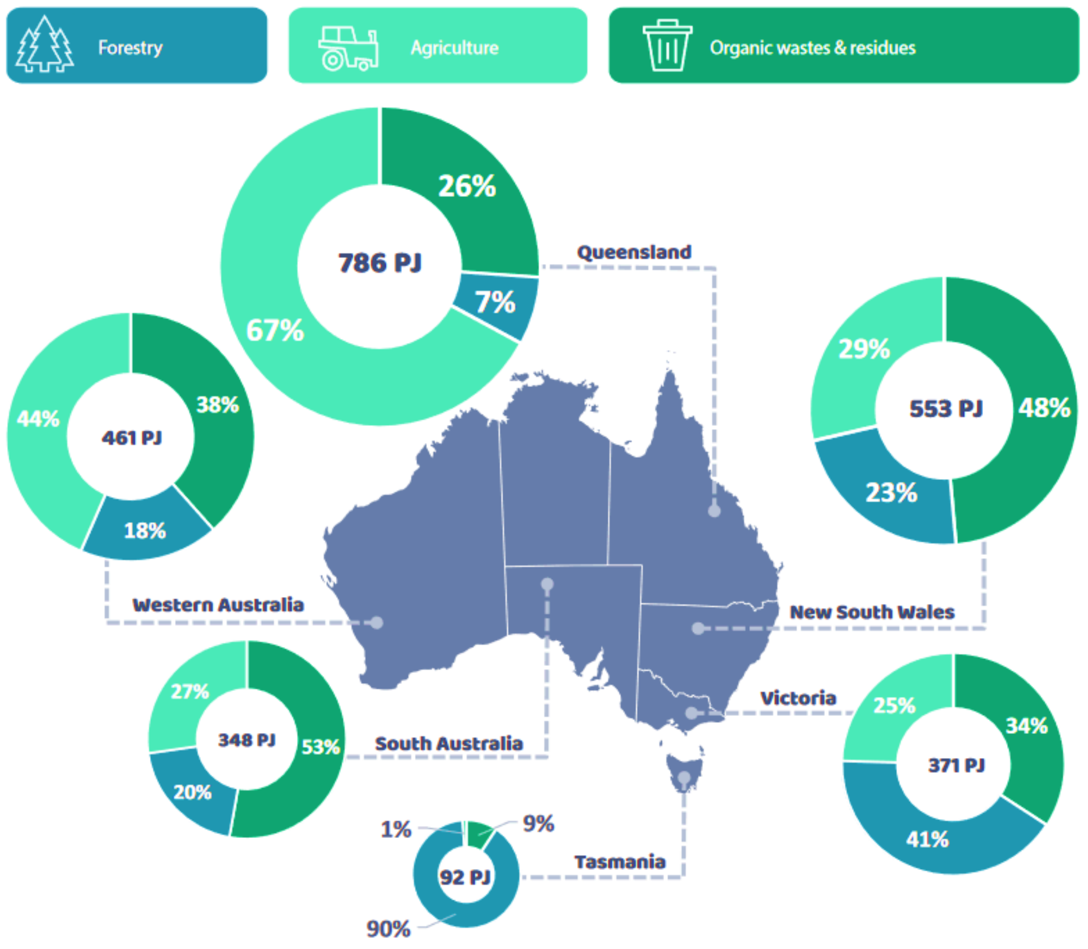
Potential Future Feedstock Production by Type and State

Potential Bioenergy Production By Feedstock and State



Source: Arena (2021)

- Australia's bioenergy potential is estimated to be over 2,600 PJ per year, which would represent
  - 40% of Australia's current energy supply
  - 10 times its current bioenergy production
- ARENA's BaU scenario assumed that only 45% of the bioenergy potential could be accessed
- Organic wastes and residues are the largest resource opportunity for developing the industry in the short term
  - This represents 37% of Australia's current potential

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US Case Study

Demand

Supply

Pricing

Costs

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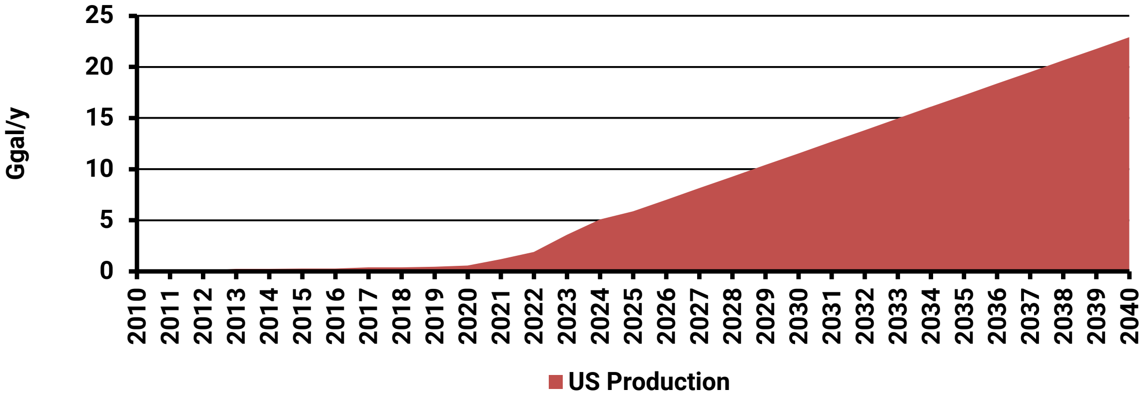
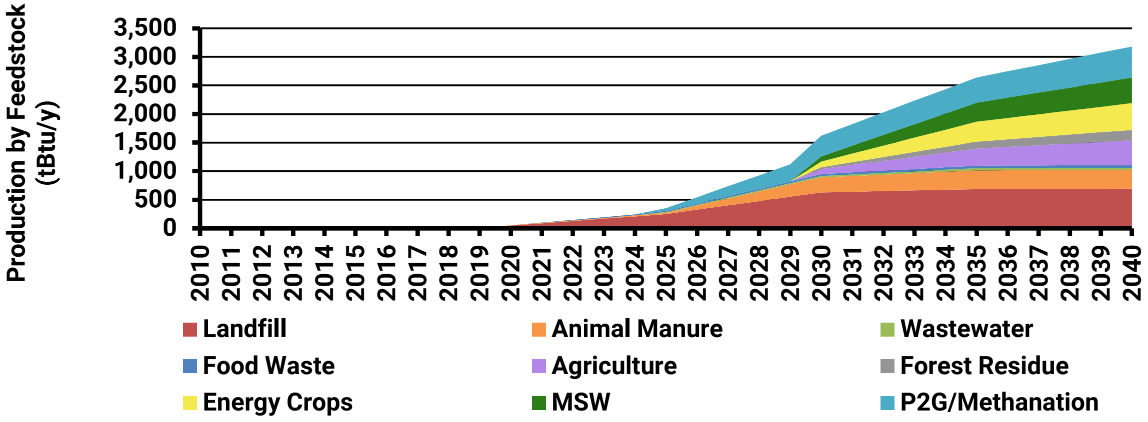
Production and Consumption Potential Outlook (Cont.)

Renewable Diesel



Source: IEA. Note: Data is trended post 2024

Renewable Natural Gas



Source: ICF

- California market has been growing strongly off the back of the LCFS market
  - Medium to longer-term trend unclear, will depend on timing of transition to hydrogen and electricity
- Market expected to grow significantly
  - Market drivers include the CA LCFS market, but also generation and industrial decarbonization

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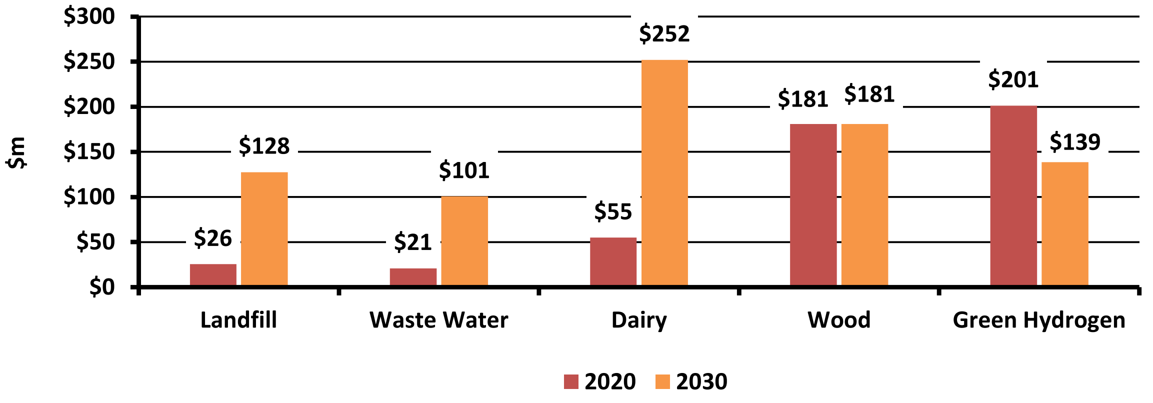
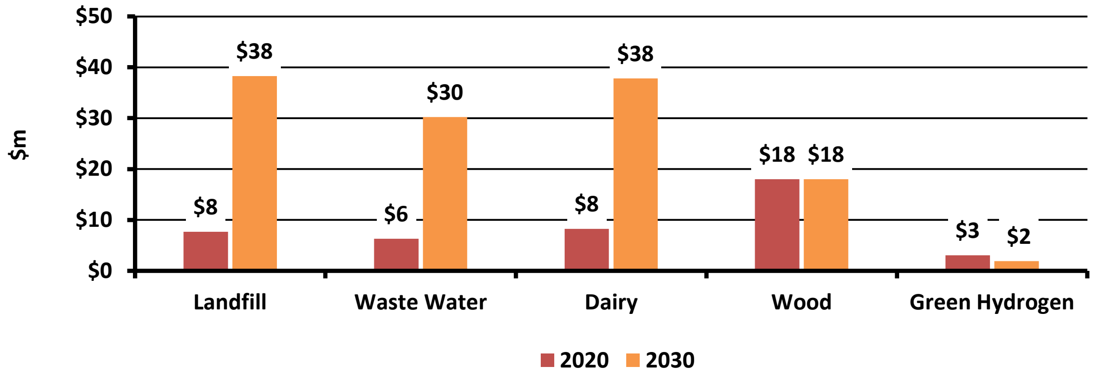
New RNG and Hydrogen Project Costs vs. Market Pricing

Project Overnight Capex by Feedstock – National ($2021)



Source: Energeia (2021)

Project Annual Opex by Feedstock – National ($2021)



Source: Energeia (2021)

- Project capex estimated to deliver target RNG MWhs, opex assumed to be 10% of capex
- Hydrogen grossed up to 100% for comparative purposes
- These prices are for 2030 projects, hydrogen project costs expected to become cheaper than RNG after 2030, excluding incentives
- Higher costs over time for drop-in replacement fuels due to lower cost projects being developed first

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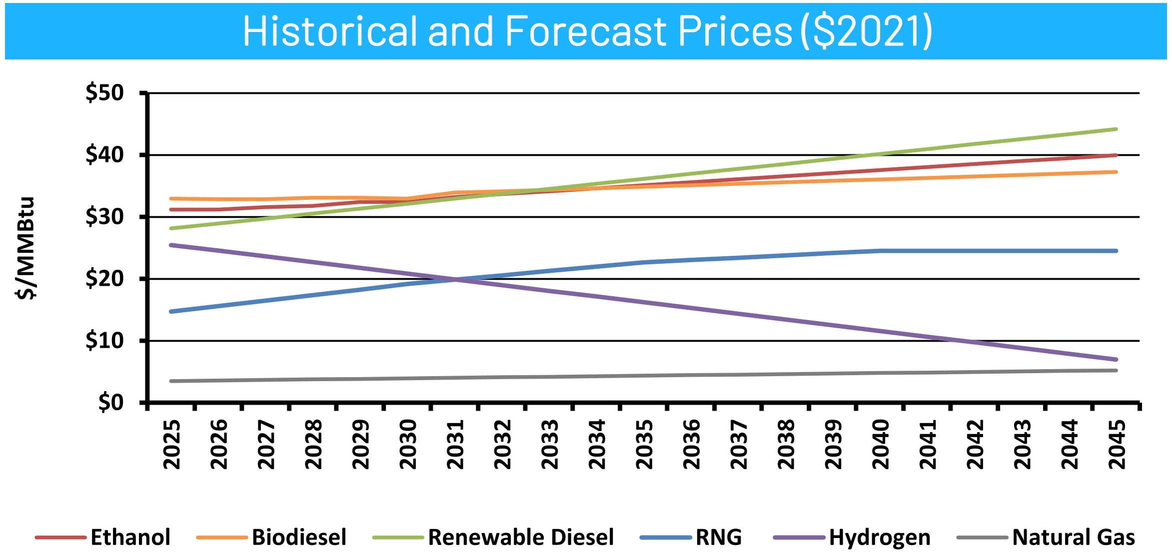
Price History and Outlook



- Liquid fuel prices expected to rise slowly, as manly a mature and larger market
- RNG prices expected to rise to bring in higher cost sources of supply
- Hydrogen prices expected to fall with input costs, but forecast price declines to date have yet to materialise

Source: EIA, 2021
Note: Ethanol and Biodiesel trended from 2015, Renewable Diesel from 2017, Natural Gas from 2016, Hydrogen with subsides from 2020 and Hydrogen without subsides from 2026

Key Conclusion for Australia

Potential Benefits

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Key Conclusions and Recommendations

- Key Conclusions
  - Drop-in biofuels could play a major role in reducing CO2 target achievement risks at lower cost
  - There is significant existing feedstock (40% of total energy needs), but its relative development costs are not well understood
  - Assuming a comparable cost structure to the U.S., it would be lower cost than Green Hydrogen up to 2030
- Key Recommendations
  - Invest in RD&D, including datasets and tools
  - Prime the market, e.g. via CO2 certificates or more targeted, enforced mandates
  - Review Federal and state Co2 targets in light of potentially lower cost, lower risk option

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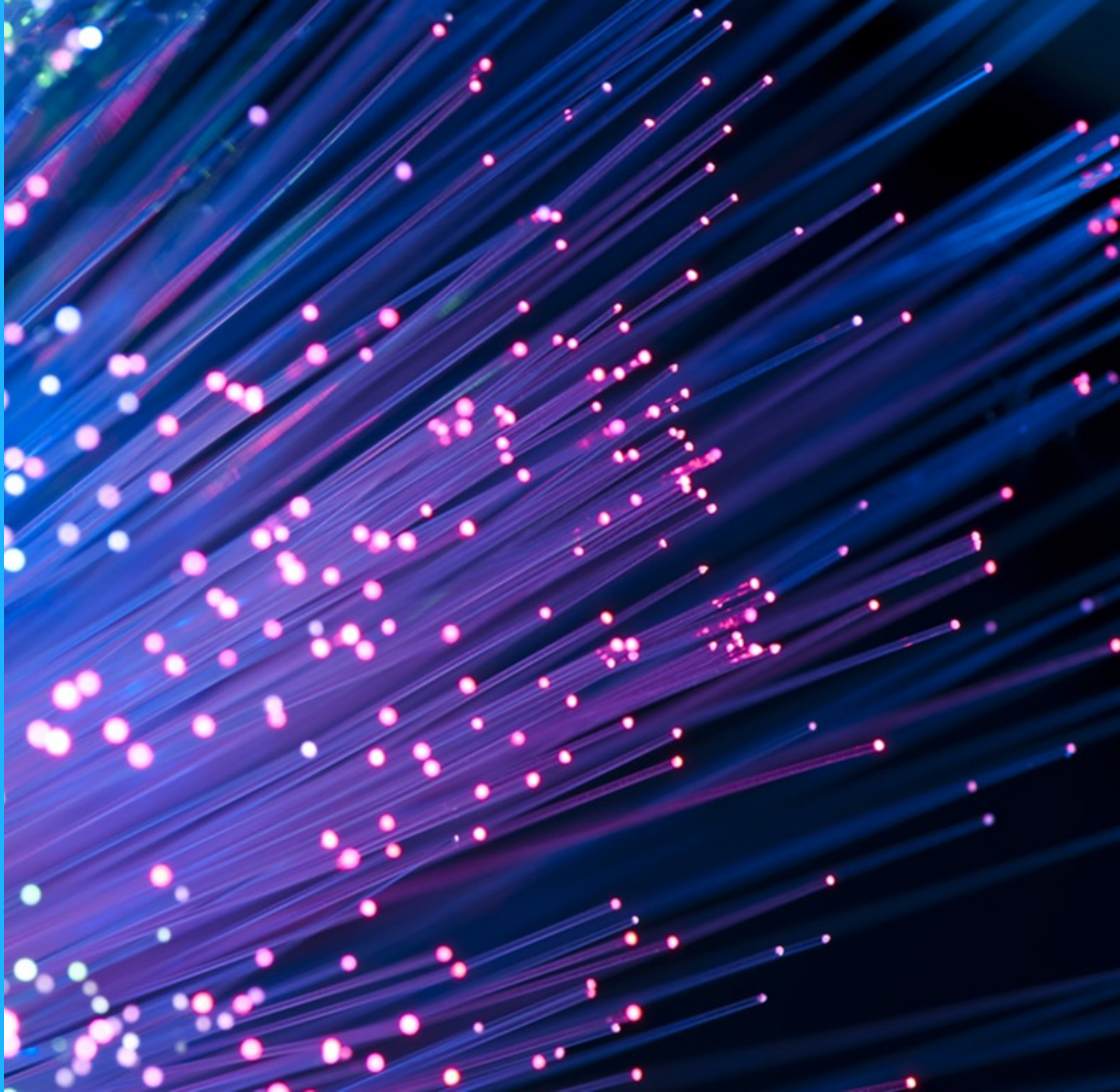
Questions

Topic Voting

Next Steps



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Energeia's Power Sessions

- Q&A
  - Add your questions in the chat
  - Unanswered questions will be answered via email.
- What topic would you most like to see in the Power Session webinar series?
  - ❑ Transitioning Commercial Fleets
  - ❑ Digitizing Load, Customers, and Behind-the-Meter (BTM) Resources
  - ❑ Drop-In, Zero-Carbon Biofuels – Part 2
- Next Steps
  - Follow the link at the end of the webinar to:
    - Request an exploratory meeting with Energeia
    - Easy access links to previous webinars
  - Expect a follow-up email to include links to the recording and presentation

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Thank You!

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