8: Appendices

Contents

Appendix A: Demand Analysis

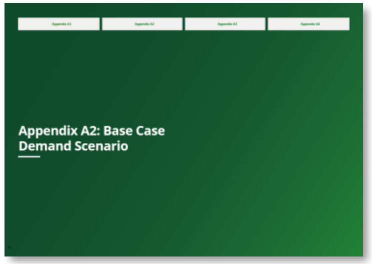
Appendix A | Demand Appendix Overview

Appendix A1 sets out the framework used to assess whether each of the 11 subsectors currently consuming liquid fuels in Australia is appropriate for LCLF sectoral analysis. It also articulates how the six focus sub-sectors were identified for more detailed analysis.

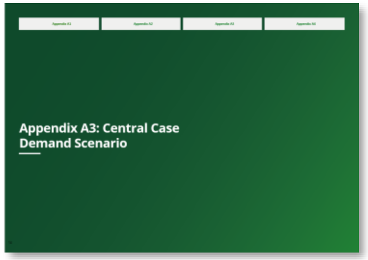
This is assessed against four criteria being share of liquid fuel consumption, share of scope 1 emissions driven by liquid fuel use, electrification potential and degree of sector concentration.

In order to understand sectoral demand for LCLFs, assumptions and calculations are set out regarding total liquid fuel demand projections and adjustments for electrification. This informs specification of the Base, Central and Accelerated demand scenarios including growth rates, policy settings and purchasing behaviour.

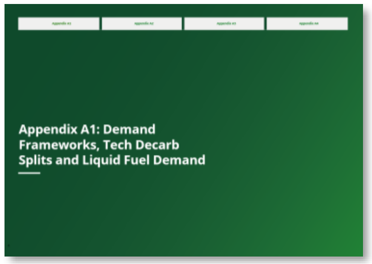
Detailed sectoral assumptions regarding decarbonisation profiles and key assumptions and calculations.



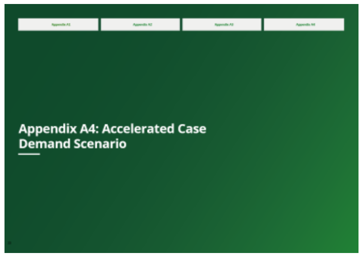
Sets out willingness to pay under the Base Case Scenario, with demand only present in aviation and construction sectors, driven by public construction and premiums paid by business and Australian government air travel customers.



Sets out the Central Case Scenario, where the Safeguard Mechanism induces abatement and hypothetical demand for LCLFs. Demand projection calculations are detailed including sectoral decarbonisation profiles and assumptions.



Sets out framework and criteria used to determine the six priority sectors studied in this report including decarbonisation technology splits and base liquid fuel demand. Sets out framework for Base, Central and Accelerated scenarios and factors considered for each.



Sets out the Accelerated Case Scenario, where Safeguard Mechanism and emulated ReFuelEU and FuelEU instruments induce abatement and hypothetical demand for LCLFs. Includes sectoral profiles and calculations where they differ from central case.

Appendix A1: Demand Frameworks, Tech Decarb Splits and Liquid Fuel Demand

Selection framework for study focus sectors

Key to Figures 4 & 20

Lower priority for sectoral analysis → Higher priority for sectoral analysis

This study focuses on six potential end users of LCLF. Table A1-1 sets out the framework used to assess whether each of the 11 subsectors currently consuming liquid fuels in Australia is appropriate for LCLF sectoral analysis.

There are four relevant criteria:

1. **Share of liquid fuel consumption:** The relative share of liquid fuel demand varies significantly across key economic sectors, with many heavily reliant on liquid fuels to service energy demand requirements.
2. **Share of scope 1 emissions driven by liquid fuel use**: For some end-users, liquid fuel use accounts for almost the entirety of the sector's scope 1 emissions profile. For others, it represents only a small share of onsite emissions.
3. **Electrification potential:** LCLF uptake is likely to be prioritised in sectors where electrification is not possible or commercially mature.
4. **Degree of sector concentration** – Each sector is uniquely concentrated, with key proponents and asset bases either dominated by a small share of operators or highly fragmented across the broader economy. LCLF uptake is likely to occur in markets with greater concentration, who will likely be subject to decarbonisation obligations.

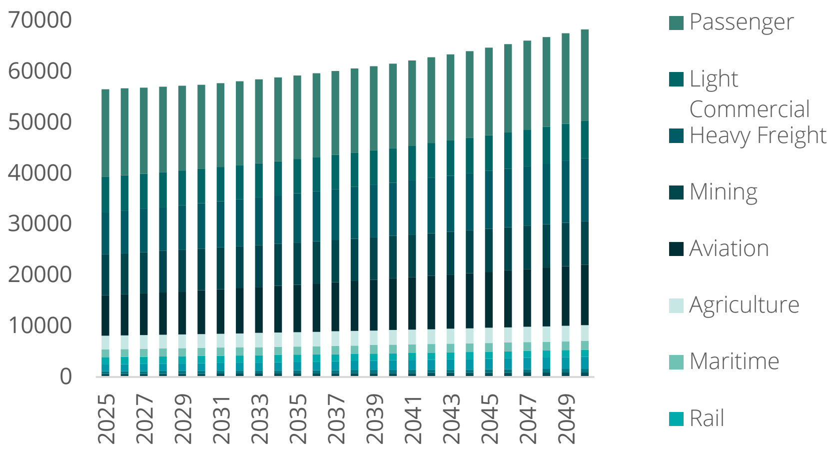
Table A1-1: Sectoral demand analysis framework*

Sector	Share of Liquid Fuel Consumption[1]	Liquid Fuel Share of Scope 1 Emissions[2]	Liquid Fuel Consumption Subject to Electrification[3]	Sector Concentration	Status
Road: Passenger	30%	100%	99%	Very Fragmented	Exclude
Road: Heavy Freight	15%	95.4%	22%	Fragmented	Include
Mining	14%	31.1% (Coal) 75.6% (Iron Ore)	75%	Concentrated	Include
Aviation	14%	99.9%	1%	Very Concentrated	Include
Road: Light Commercial	12%	100%	96%	Very Fragmented	Exclude
Agriculture	5%	9%	72%	Very Fragmented	Exclude
Maritime	3%	92%	0%	Concentrated	Include
Rail	3%	93.3%	20%	Concentrated	Include
Utilities	2%	2.3%	67%	Concentrated	Exclude
Construction	1%	88.5%	57%	Fragmented	Include
Manufacturing	1%	3%	80%	Fragmented	Exclude

*Notes: *The electrification potential and concentration of each sector were considered most significant when determining the focus sectors of this study. 1. Liquid fuel share of production is based upon fuel demand estimates developed by DCCEEW. 2. Liquid fuel share of scope 1 emissions developed as a weighted-average of sample sector company emissions. 3. Liquid fuel consumption subject to electrification developed based upon methodology outlined in overlay pages.*

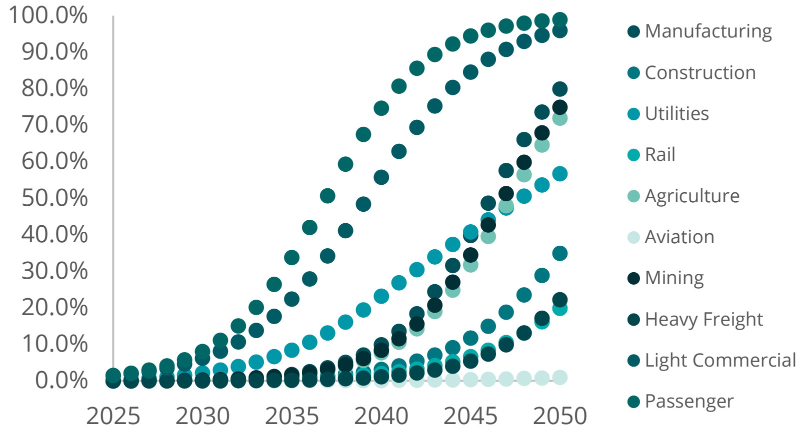
Modelling Future Liquid Fuel Demand and Electrification

Figure A1-0: Liquid fuel demand by sector



Electrification adoption curves are applied to projected fuel demand for each sector

Figure A1-1: Assumed electrification adoption curve[1]

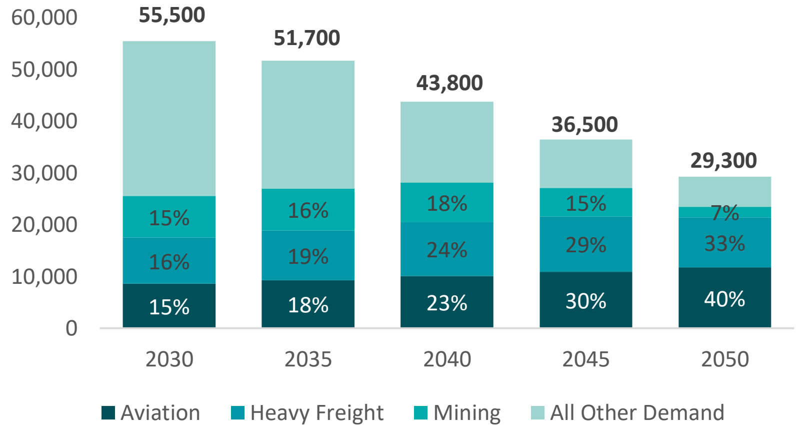


Projection of fuel demand to 2050 is derived using growth projection multiplied by electrification rate fitted to an adoption curve for each of the 11 sectors.

1. Liquid fuel demand to 2050 is projected for each sector considered in the study selection framework.
2. The electrification adoption curve is then derived based on current electrification rates and 2050 electrification rates. It assumes electrification will be lower in the earlier years (e.g. 2025 to 2030) and grow at a faster rate afterwards as technologies become more mature and commercially available for uptake. This will flatten in most cases as a threshold is approached.
3. Adjusting the projected liquid fuel demand for electrification yields a residual liquid fuel demand projection for each sector studied. These figures provide the foundation for reference regarding fuel security across the study.

Yielding a residual liquid fuel demand projection for each sector

Figure A1-2: Residual liquid fuel demand by sector



Note: 1. Maritime sector is excluded as no electrification is assumed (see inputs and assumptions on next page).

Decarbonisation technology split sources

Key to Figures 5, 6, 8 & 12

Table A1-2: Sectoral decarbonisation splits

Sector	Decarbonisation technology split 2050, %				Source(s)
	Electrification	LCLFs (incl. synthetic fuels)	Hydrogen (direct use)	Fossil fuels	
Manufacturing	79	10	10	1	Australian Industry ETI; Pathways to industrial decarbonisation (2023)
Construction	57	39	4	0	Adoption curve developed based on UQ Construction Decarbonisation Report and Australian Construction Association assessment that 60% of construction equipment could electrify by 2040. Electrification share of fleet is calculated based on a 50% turnover of construction equipment each decade consistent with ATO depreciation schedule and based on Arizton Australian Construction Market Assessment size of equipment fleet. Hydrogen fuel cell market share is based on heavy freight. Fossil fuel use is assumed to decline linearly to 2050 with LCLF covering the residual.
Utilities	67	10	0	23	Based on the weighted average renewable/gas/diesel split across 5 Zenith Energy off grid power solutions: Mt Weld, Jundee, Nova, Kathleen Valley, and Bellevue Gold. Further informed by NREL; Is a Generator the Only Solution When the Grid Fails? (2024) (replacement of diesel generators with PV/BESS)
Rail	20	75	5	0	Two adoption curves are assumed – one for the Pilbara which accounts for ~30% of rail emissions and one for remaining rail freight. Sale of battery locomotives is assumed to reach 50% by 2040 for Pilbara operations, and the same number in 2050 for remaining operations, consistent with the Australasian Railway Association; The critical path to decarbonise Australia's rail rollingstock (2024). An average asset age of 27.5 is assumed from the ARA report and an asset cycle of 40 years. Pilbara operations reach 42% electrification by 2050, with the remaining rail freight at 10% at the same time. The majority of the residual is assumed to be delivered by LCLFs.
Maritime	0	80	0	20	IRENA; A pathway to decarbonise the shipping sector by 2050 (2021) [1.5°C Scenario] and IEA; Net zero by 2050 (2021) [Net Zero Emissions scenario]
Agriculture	72	18	0	10	Informed by NREL; Pathways for Agricultural Decarbonisation in the United States (2024) and AgriFutures; Powering Australian agriculture's future (2024)
Aviation	1	75	1	23	IEA; Net zero by 2050 (2023) [Net Zero Emissions scenario]
Mining	75	25	0	0	Informed by stakeholder consultations and Rio Tinto; Transitioning our Diesel Fleet (2024)
Heavy Freight (Road)	22	49	1	28	An adoption curve is developed based on EV (85% 2050 sales) and H2 sales (15% 2050 sales) from Mission Possible Partnership; Making zero Emissions, 1.5°C aligned Trucking Possible (2022) [Zero-Emissions scenario]. Fleet turnover is estimated based on vehicle registration & sales data from BITRE, 2024 Road Vehicles in Australia January 2024. Fossil fuel share in 2050 is based on the fraction of registered heavy freight older than 20 years (assumed to roll over in next 5 years and not again before 2050). LCLFs assumed for residual.
Light Commercial (Road)	96	0	0	4	Up to date share of light commercial vehicles in total EV sales obtained from the Truck Industry Council; Low and zero Emission Trucks Discussion Paper (2023). Assumed to follow the same trajectory as passenger vehicle electrification, but with a 10 year delay. 2050 value sourced from CSIRO; Electric vehicle projections (2023) [Step Change scenario].
Passenger (Road)	99	0	0	1	CSIRO; Electric vehicle projections (2023) [Step Change scenario].

Demand scenario framework

Table A1-3: Demand analysis scenario framework

	Factors	Base Scenario	Central Scenario	Accelerated Scenario
1	**Sector Coverage**	Six major sectors: aviation, mining, road freight, rail freight, maritime, construction		
2	**Sector Growth Rates**	Consistent growth assumptions (e.g. BITRE freight forecasts)		
3	**Policy Settings**	1. Safeguard Mechanism – No ACCU Limit	1. Safeguard Mechanism – 30% ACCU Cap, with trade exposed facilities expected to reduce emissions in line with other facilities	1. Safeguard Mechanism – In line with mid case 2. RefuelEU SAF and Maritime Mandates applied to Australian context
4	**Technology Competition**	1. ACCU purchase 2. Electrification 3. Biofuel 4. Hydrogen derivatives		
5	**Purchasing Behaviour**	1. Assumption that majority of demand = Fossil incumbent price + ACCU price 2. Demand = Premium Demand for Aviation (Business & Australian Government Travellers) and Construction (Public Construction)	1. Assumption that majority of demand = Fossil incumbent price + ACCU price 2. Demand = Forced SGM Demand across five sectors + Base case construction + Defence aviation demand	1. Assumption that majority of demand = Fossil incumbent price + ACCU price 2. Demand = Forced SGM demand + base case construction + Mandates for Aviation and Maritime

Demand projections across scenarios use a base liquid fuel demand and associated growth rate and efficiency consideration

Key to Figure 21

Table A1-4: Sectoral liquid fuel demand (2022–23)

Sector	Base Fuel Demand (ML)	Annual Growth Rate (%)	Efficiency Rate (%)	Sources
Heavy Freight (Road)	8,220 (rigid & articulated trucks)	2.22	0.60	**Base fuel demand**: DCCEEW; Australian Energy Update 2024 – Table F (2024) **Growth rate**: From NFDH; Road freight (2023) **Efficiency rate:** ABS; historical efficiency improvement.
Mining	7,990 (iron ore & coal)	1.04 (Iron ore*) -1.05 (Coal*)	0.80	**Base fuel demand**: DCCEEW; Australian Energy Update 2024 – Table F (2024) **Growth rate**: BITRE; Australian aggregate freight forecasts – 2022 update (2022) **Efficiency rate:** IEA; Environmental Protection (CAEP12) for fuel burn improvements due to new fleet replacement under moderate technology improvement.
Aviation	7,850	2.60	0.96	**Base fuel demand**: DCCEEW; Australian Energy Update 2024 – Table F (2024) **Growth rate**: BITRE; Australian aviation forecasts – 2024 to 2050 (2024) **Efficiency rate:** ICAO; Environmental Trends in Aviation to 2050.
Rail	1,440	0.18	0.40	**Base fuel demand**: DCCEEW; Australian Energy Update 2024 – Table F (2024) **Growth rate**: BITRE; Australian aggregate freight forecasts – 2022 update (2022) **Efficiency rate:** Aurizon holdings Limited; Preliminary Financial Report (2021).
Maritime	460	0.50	-	**Base fuel demand**: DCCEEW; Australian Energy Update 2024 – Table F (2024) **Growth rate**: From BITRE; Australian Sea Freight 2020 - 21 (2023) **Efficiency rate:** N/A.
Construction	715	2.00	0.80	**Base fuel demand**: DCCEEW; Australian Energy Update 2024 – Table F (2024) **Growth rate**: Global Data; Australian Construction Market Size, Trend Analysis by Sector, Competitive Landscape & Forecast to 2028 – Q4 Update (2024) **Efficiency rate:** IEA; Improvements in fuel consumption /conventional engines slowed to 0.8% per year between 2015 and 2019.

Notes: *Considers the global growth rate of iron ore and coal mining.

Appendix A2: Base Case Demand Scenario

Base Case | Willingness to pay by sector and fuel uptake

It is well understood that LCLFs currently have a cost premium relative to fossil fuels. This means that the cost of LCLF production is higher than what fuel purchasers are willing to pay. Willingness to Pay (WTP) in this context means the cost of the fossil fuel with a premium for the carbon abatement. The most common decarbonisation cost is considered the price of a carbon offset (i.e., ACCUs) – often expressed as the ceiling on Safeguard Mechanism Credits (SMCs).

A rational fuel user will not purchase LCLF if its price exceeds their WTP, as this would lead to value destruction. Additionally, a fuel user's willingness to pay will only increase in line with the price of an ACCU. Given the persistently high price of LCLF, the lack of market formation in Australia is reflective of potential purchasers behaving in this way.

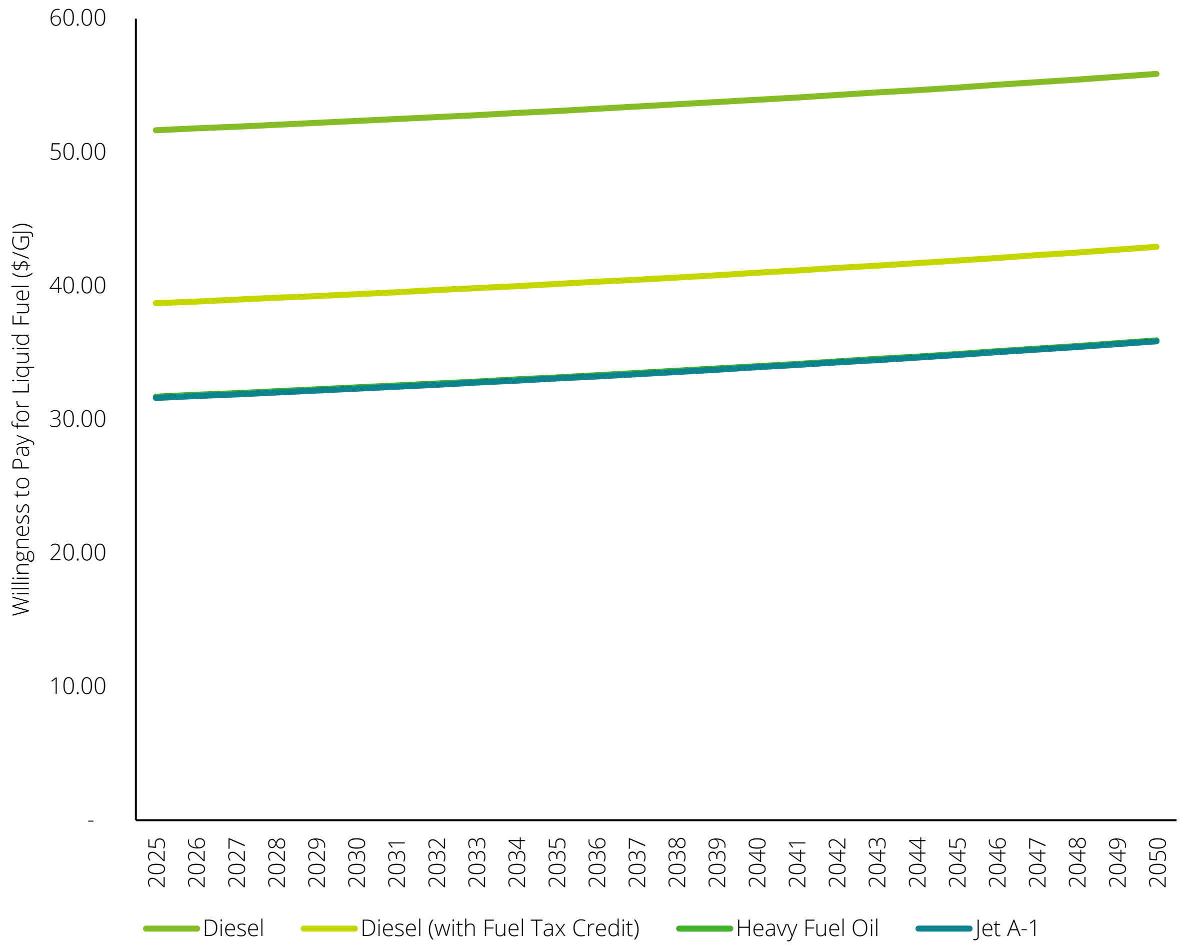
As Figure A2-1 shows, WTP varies significantly for each sector. This is because some fossil fuels such as Heavy Fuel Oil (Maritime) and Jet-A1 are cheap. Furthermore, in other instances perverse policy outcomes are distorting the market, such as fossil fuels being eligible for the Fuel Tax Credit while LCLFs are currently not.

It is clear that in all cases, the WTP of each of these sector remains below the cost of typical LCLFs. This suggests that on the current cost trajectory, rational fuel users will not purchase LCLFs. This work assumes the cost of the incumbent fuel remains constant over time whilst the carbon premium grows at 2% per annum from a \$75/tCO_2-e base.

Despite this, fuel users may have customers with a higher WTP for decarbonisation. Interviews suggested that this is particularly likely to be the case in aviation where corporates with large scope 3 travel footprints would be willing to pay a large premium to reduce this. There is also evidence from the UK that governments may be willing to pay more to reduce scope 3 emissions from public infrastructure works.

Given the potential persistence of a cost gap for LCLFs without fuel cost reductions or policy intervention, the Base Case only includes demand from these premium customer segments that interviews suggested would have a WTP materially above a prevailing fossil and offset cost.

Figure A2-1: Comparison of willingness to pay for LCLF by incumbent fuel being replaced and inclusive of a carbon cost component[1]



*Notes: *Rail, Mining and Construction sectors are eligible for Diesel Tax Credit. 1. Underlying fuel costs based upon: Jet A-1 – IATA Asia & Oceania Price; Heavy Fuel Oil – EIA No. 2 Heating Oil; Diesel – Australian Petroleum Institute; Fuel Tax Credit – ATO Fuel Tax Credit Rates from 1 July 2024 to 30 June 2025. Willingness to pay incorporates a carbon cost component reflecting a \$75/tCO_2-e carbon price in 2025 growing at 2% in real terms.*

Base Case | Calculations

Figure A2-2: Base Case aviation demand calculation

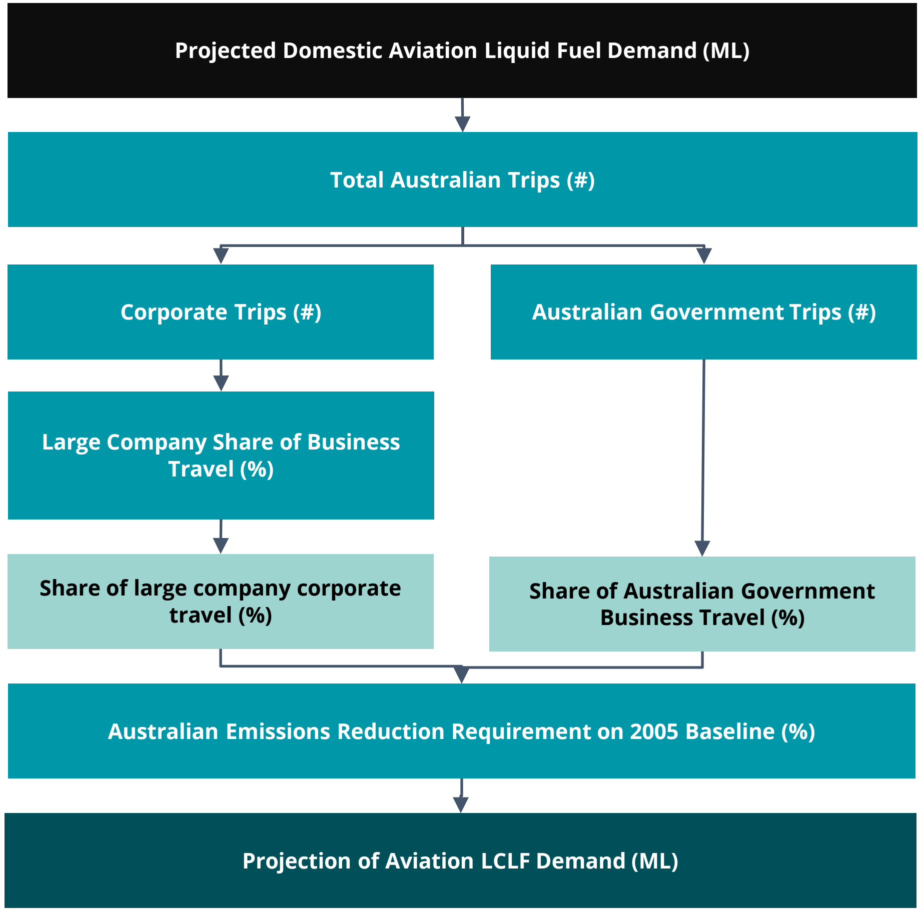


Table A2-1: Aviation sector key assumptions and calculations

Assumption	Sub-Assumptions	Units	Quantum	Source
Total Domestic Australian Trips		Million trips per annum	61.32	BITRE (2023)
Share of ASX (large company) business travel	Corporate Trips	Million trips per annum	11.97	Considers overnight and day trips from Tourism Research Australia; NVS Quarterly June 2024 (2024)
	Large Company Share of Business Travel	Employment Share (%)	45.75	Assumed employment share aligns with trip numbers. ABS; Jobs in Australia (2024)
		%	8.93	
Share of Australian Government business travel	Australian Government Trips	Trips per annum	913,582	Estimated from average airfare and government spend across Virgin and Qantas. Virgin Australia ;Response to Aviation Green Paper (2023)
		%	1.49	
Australian emissions targets	2030 target below 2005 levels	%	43	Adoption is tapered utilising the Australian emissions reduction target. APH; Climate Change Bill 2022 (2022) DCCEEW; Australian National Greenhouse Accounts Factors (2024)
	2050 target below 2005 levels	%	100	
Assumed renewable fuel abatement		%	80	Assumed abatement comparable to UK Department of Transport

Base Case | Calculations

Figure A2-3: Base Case construction demand calculation

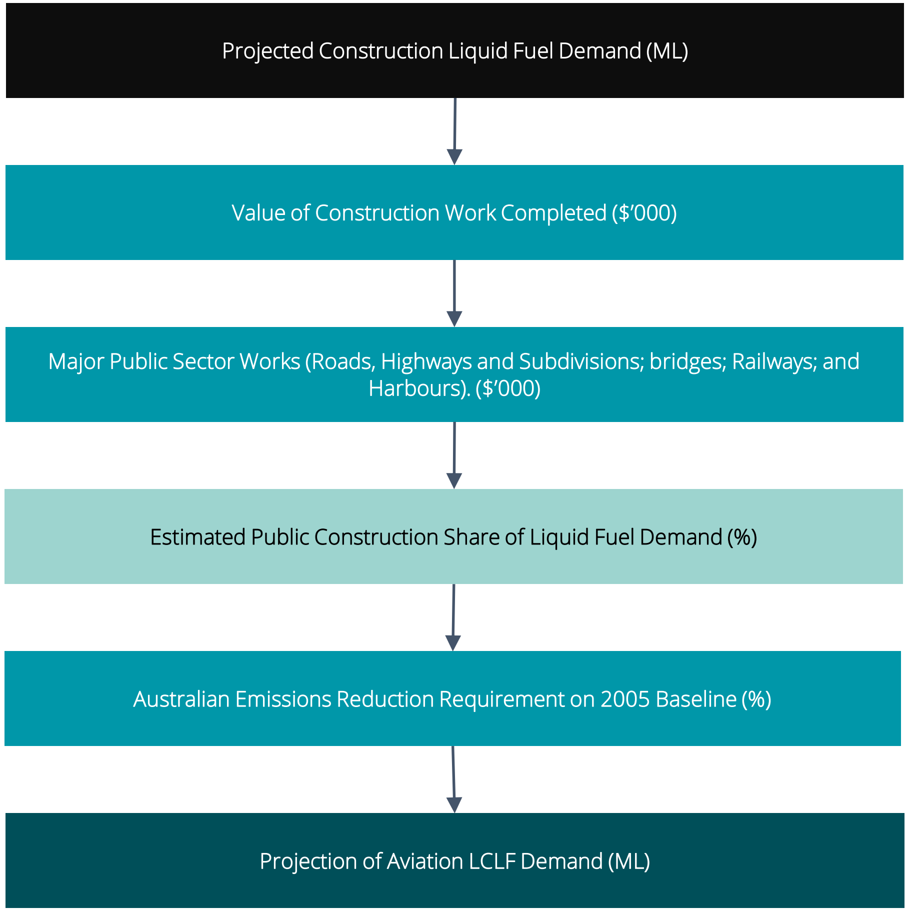


Table A2-2: Construction sector key assumptions and calculations

Assumption	Sub-Assumptions	Units	Quantum	Source
Construction Share of Liquid Fuel Demand	Value of Construction Work Completed	($b, 2023–24)	$139.4	ABS Engineering Construction Activity Australia
	Major Public Sector Works (Roads, Highways and Subdivisions; bridges; Railways; and Harbours).	($b, 2023–24)	$10.7	ABS Engineering Construction Activity Australia
		%	**7.70**	
Australian emissions targets		%	43% below 2005 levels (2030) 100% (2050)	Adoption is tapered utilising the Australian emissions reduction target. DCCEEW; Australian National Greenhouse Accounts Factors (2023)
Assumed renewable fuel abatement		%	80	Assumed abatement comparable to UK Department of Transport

Appendix A3: Central Case Demand Scenario

Central Case | Included sectors

The key difference between the Base Case and the Central Case is hypothetical adjustments to the Safeguard Mechanism to force operational abatement. Using the Safeguard Mechanism as a policy lever was chosen as it is existing policy and creates a direct incentive to decarbonise. The policy was assumed to be adapted by:

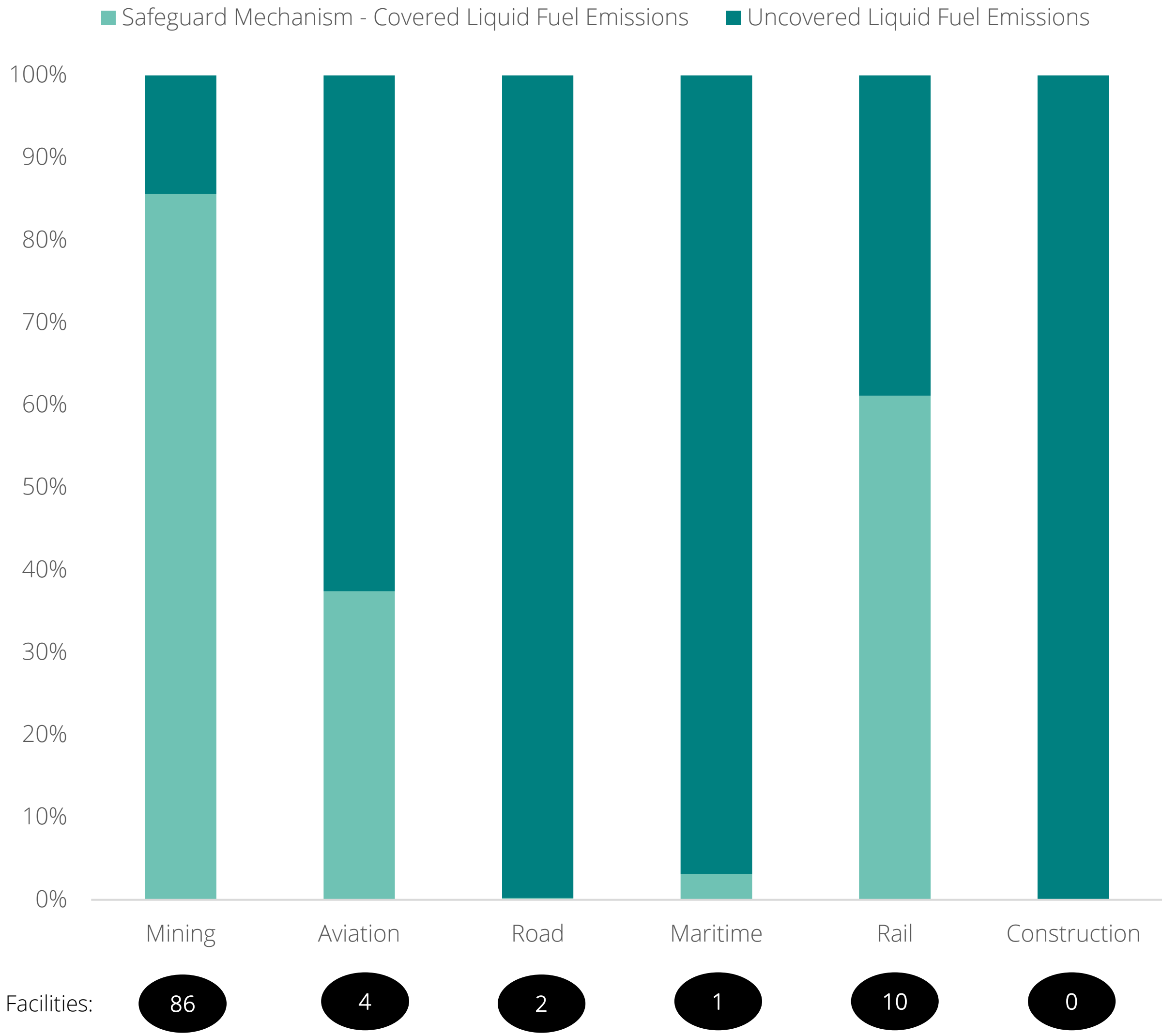
- Creating a hard limit on ACCU/SMC use at 30% of the baseline. The ACCU/SMC use subsequently declines as the baseline declines, reaching zero by 2050. This adapts the existing soft offset limit imposed by CER which shows a clear preference for on-site decarbonisation.
- Removing the trade-exposed baseline-adjusted (TEBA) classification, with all facilities experiencing the same baseline emissions reduction rate.

Importantly, the Safeguard Mechanism does not apply to the six focus sectors equally because only facilities with scope 1 emissions over 100,000 t CO_2-e p.a. are covered. Figure A3-1 shows that the Safeguard Mechanism covers a very high share of emissions in the mining and rail sectors, but only domestic aviation. Coverage in road, maritime and construction is very limited. As a direct consequence, demand from these sectors is limited in both the Central Case and Accelerated Case.

There has been public commentary from the Productivity Commission that a revision to the qualifying threshold for the Safeguard Mechanism to 25 kt CO_2-e would substantially increase coverage of liquid fuel users. This extension of the policy has not been considered in the analysis used in this paper.

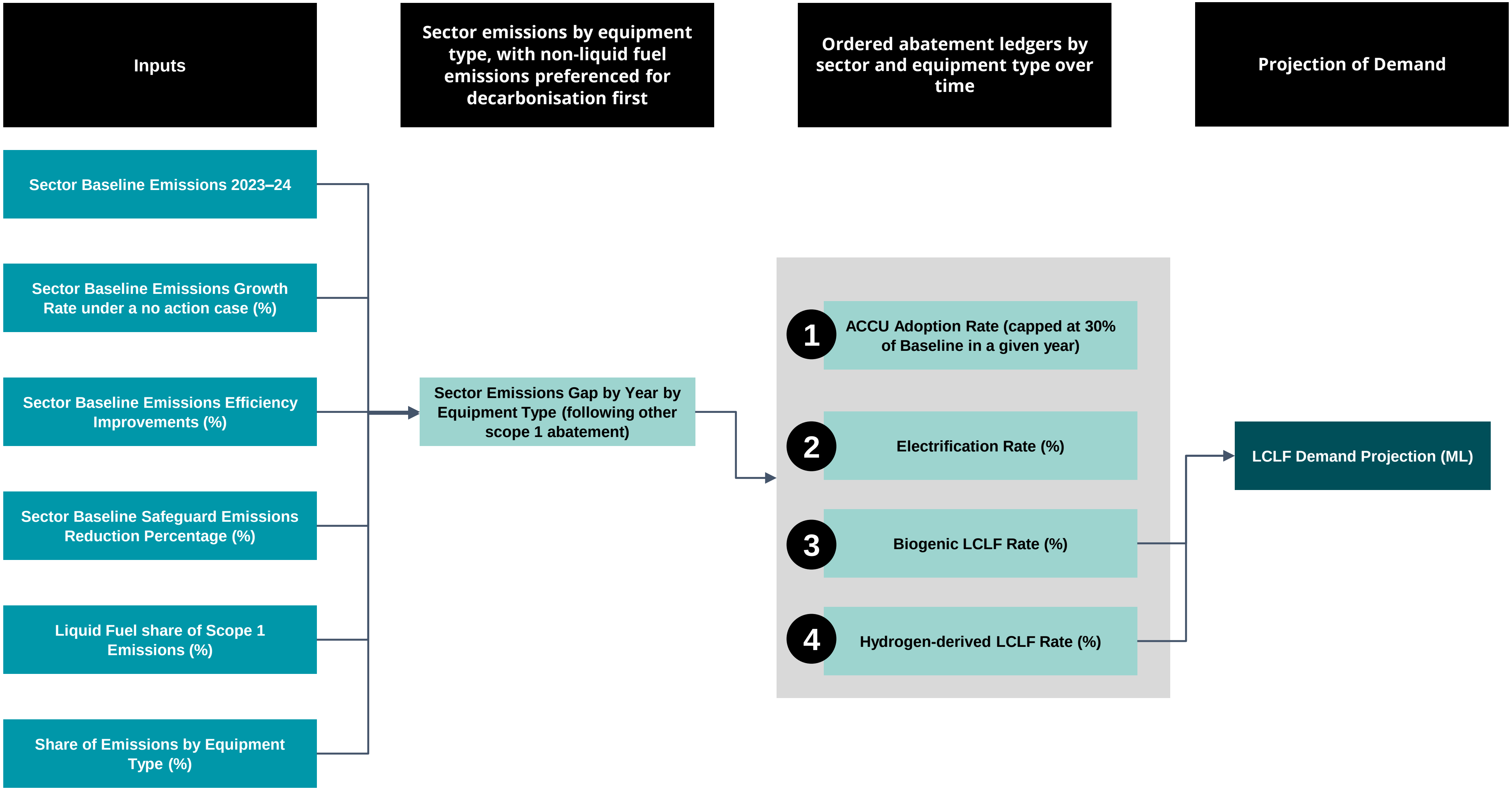
Alternative incentives would be needed to lift the WTP of fuel users not covered by the Safeguard Mechanism.

Figure A3-1: Safeguard Mechanism coverage of liquid fuel emissions



Central Case | Calculations

Figure A3-1: Safeguard Mechanism coverage of liquid fuel emissions



Central Case | Aviation sector assumptions

Figure A3-3: Aviation decarbonisation profile (2024 to 2050) in central scenario

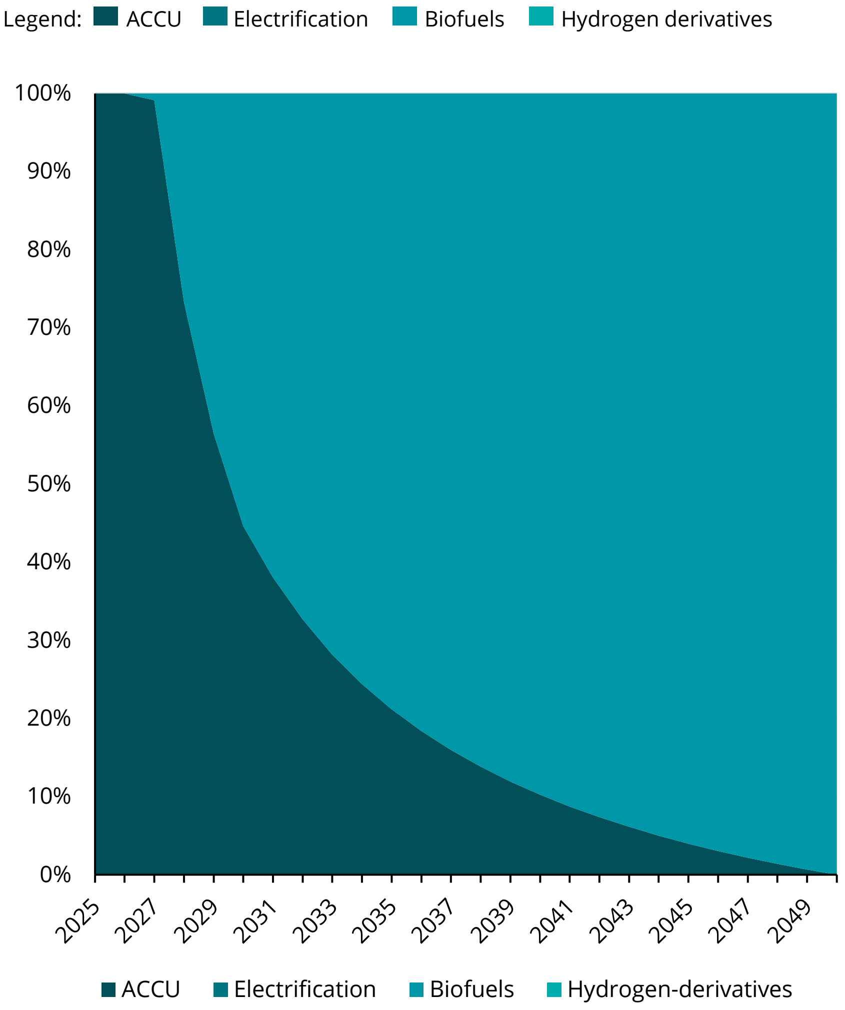


Table A3-1: Aviation sector key assumptions and calculations

Assumption	Sub-assumption	Units	Quantum	Source
Sector Baseline Emissions		Mt CO_2-e	7.68	CER Safeguard Facility Reported Emissions Data (2022–23)
Sector Baseline Emissions Growth Rate		%	2.6	BITRE; Australian aviation forecasts – 2024 to 2050 (2024
Sector Baseline Emissions Adjustment for Efficiency		%	0.96	ICAO; Environmental Trends in Aviation to 2050.
Safeguard Mechanism abatement rate	To 2030	% p.a.	4.90	CER; Safeguard baselines (2024)
	2030 - 2050	% p.a.	3.83	
Liquid fuel use share of scope 1 emissions		%	99.85	Average of Qantas and Virgin liquid fuel shares of scope 1 emissions.
Equipment Share of Liquid Fuel Use Scope 1 Emissions		%	100	Only aircraft considered.
Abatement share (2050)	ACCUs	%	30	Applied cap limit.
	Electrification	%	0	Assumed no viable electrification.
	LCLFs	%	100	Assumed to offer lower marginal abatement cost then hydrogen derivatives. Feedstock limits apply within market clearing to limit supply.
	Hydrogen derivatives	%	100	Assumed to be the last option for decarbonisation.

Central Case | Rail sector assumptions

Figure A3-4: Rail decarbonisation profile (2024 to 2050) in central scenario

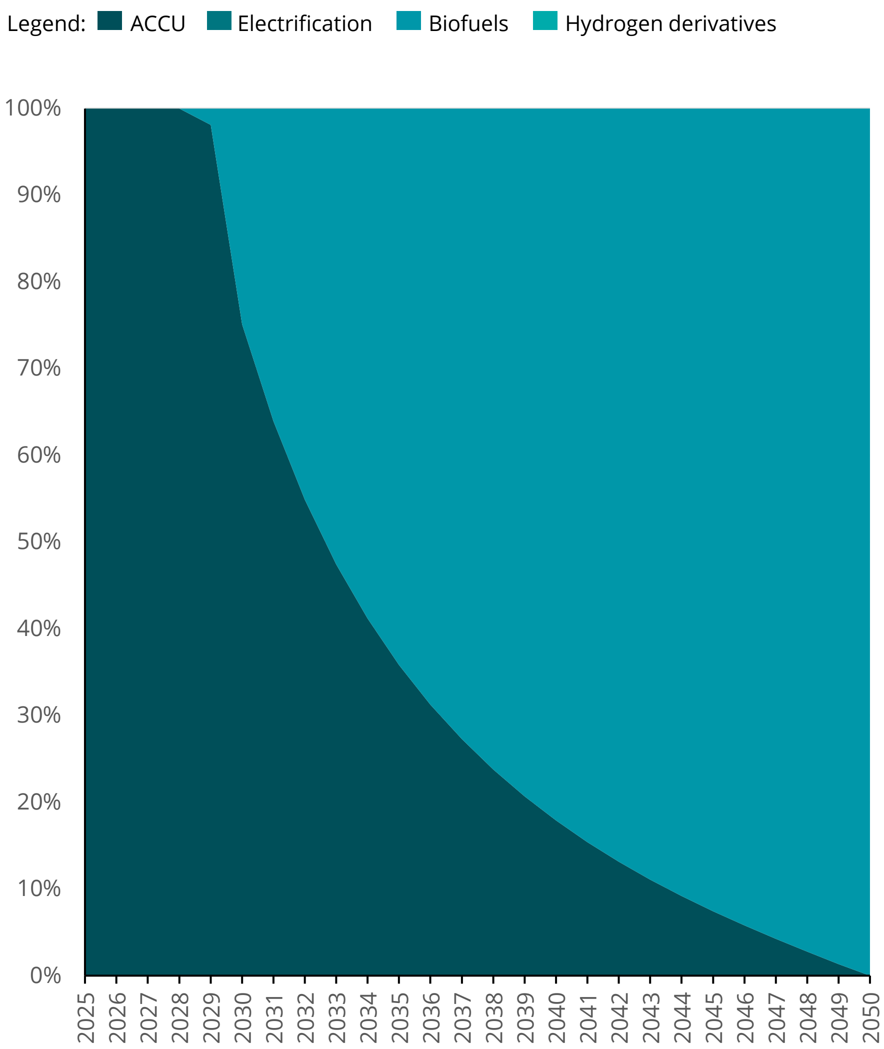


Table A3-2: Rail sector key assumptions and calculations

Assumption	Sub-assumption	Units	Quantum	Source
Sector Baseline Emissions		Mt CO_2-e	2.56	CER Safeguard Facility Reported Emissions Data (2022–23)
Sector Baseline Emissions Growth Rate		%	0.18	BITRE; Australian aggregate freight forecasts – 2022 update (2022)
Sector Baseline Emissions Adjustment for Efficiency		%	0.40	Aurizon holdings Limited; Preliminary Financial Report (2021).
Safeguard Mechanism abatement rate		% p.a.	4.9 (to 2030) 3.83 (2030 to 2050)	CER; Safeguard baselines (2024)
Liquid fuel use share of scope 1 emissions		%	93.28	Aurizon Sustainability Report (2024)
Equipment Share of Liquid Fuel Use Scope 1 Emissions		%	100	Only haulage trains considered.
Abatement share (2050)	ACCUs	%	30	Applied Cap limit.
	Electrification	%	20	Electrification is assumed to grow over time from
	LCLFs	%	100	Assumed to offer lower marginal cost decarbonisation then hydrogen derivatives. Feedstock limits apply within market clearing to limit supply.
	Hydrogen derivatives	%	100	Assumed to be the last option for decarbonisation.

Central Case | Coal mining sector assumptions

Legend: ACCU Electrification Biofuels Hydrogen derivatives

Figure A3-5: Coal mining decarbonisation profiles (2024 to 2050) in central and accelerated scenario - Off-highway haul trucks, excavator, crawler dozer and wheel loader

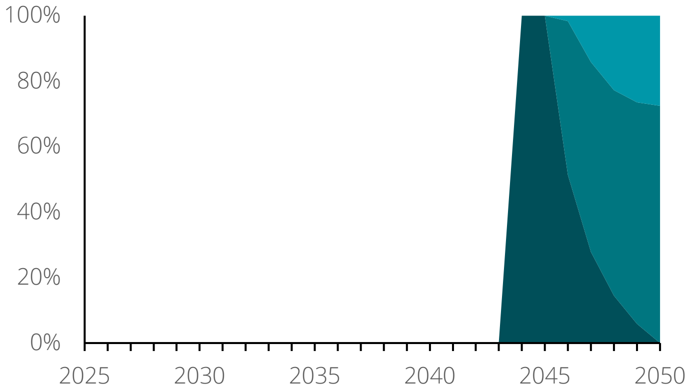


Figure A3-6: Coal mining decarbonisation profiles (2024 to 2050) in central and accelerated scenario - Generators and ancillary equipment

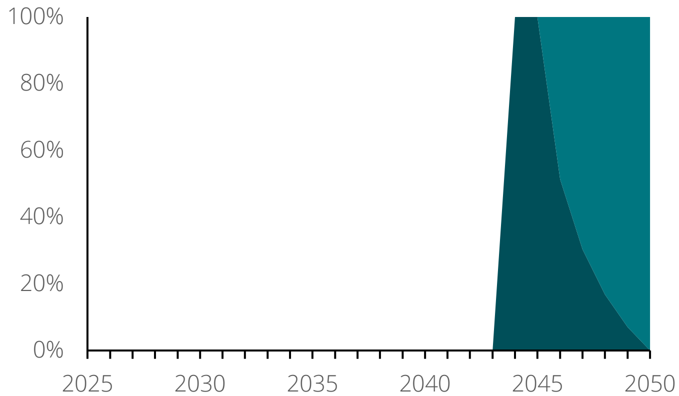


Table A3-3: Coal Mining sector key assumptions and calculations

Assumption	Sub-assumption	Units	Quantum	Source
Sector Baseline Emissions		Mt CO_2-e	43.12	CER Safeguard Facility Reported Emissions Data (2022–23)
Sector Baseline Emissions Growth Rate		%	-1.05	BITRE; Australian aggregate freight forecasts – 2022 update (2022)
Sector Baseline Emissions Adjustment for Efficiency		%	0.8	IEA; Environmental Protection (CAEP12) for fuel burn improvements due to new fleet replacement under moderate technology improvement.
Safeguard Mechanism abatement rate		% p.a.	4.9 (to 2030) 3.83 (2030 to 2050)	CER; Safeguard baselines (2024)
Liquid fuel use share of scope 1 emissions		%	31.14	Assumed to align with share at Glencore; ESG Data Book (2023)
Equipment Share of Liquid Fuel Use Scope 1 Emissions	Off-highway Haul Trucks	%	57.49	NSW EPA
	Excavator		17.92	
	Crawler Dozers:		11.09	
	Generator		7.26	
	Ancillary Equipment		3.23	
	Wheel Loader		3.00	
Abatement share (2050) **Group 1**: off-highway haul trucks, excavators, crawler dozers and wheel loaders **Group 2**: Generators and ancillary equipment	Group 1 - ACCUs	%	30	Applied Cap limit.
	Group 2 - ACCUs	%	30	
	Group 1 - Electrification	%	0	Top: Assumed no viable electrification. Bottom: Where electrification occurs, it is in line with adoption rates for road transport from IEA.
	Group 2 - Electrification	%	75	
	Group 1 - LCLFs	%	100	Assumed to offer lower marginal cost decarbonisation then hydrogen derivatives. Feedstock limits apply within market clearing to limit supply.
	Group 2 - LCLFs	%	100	
	Group 1 - Hydrogen derivatives	%	100	Assumed to be the last option for decarbonisation.
	Group 2 - Hydrogen derivatives	%	100	

Central Case | Iron mining sector assumptions

Legend: ACCU, Electrification, Biofuels, Hydrogen derivatives

Figure A3-7: Iron mining decarbonisation profiles (2024 to 2050) in Central Case - Off-highway haul trucks, excavator, drilling and blasting equipment

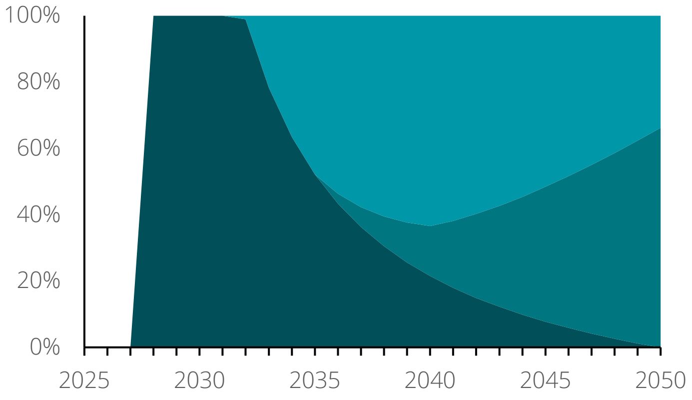


Figure A3-8: Iron mining decarbonisation profiles (2024 to 2050) in Central Case - Generators and ancillary equipment

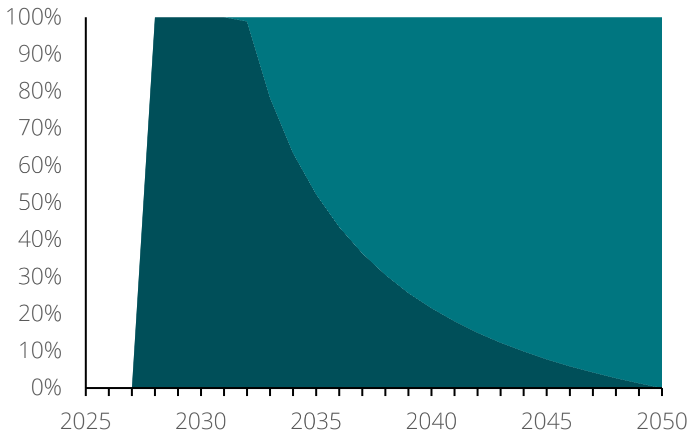


Table A3-4: Iron Mining sector key assumptions and calculations

Assumption	Sub-assumption	Units	Quantum	Source
Sector Baseline Emissions		Mt CO_2-e	7.04	CER Safeguard Facility Reported Emissions Data (2022–23)
Sector Baseline Emissions Growth Rate		%	1.04	BITRE; Australian aggregate freight forecasts – 2022 update (2022)
Sector Baseline Emissions Adjustment for Efficiency		%	0.8	IEA; Environmental Protection (CAEP12) for fuel burn improvements due to new fleet replacement under moderate technology improvement.
Safeguard Mechanism abatement rate		% p.a.	4.9 (to 2030) 3.83 (2030 to 2050)	CER; Safeguard baselines (2024)
Liquid fuel use share of scope 1 emissions		%	75.61	Assumed to align with share at BHP; ESG Standards and Databook (2024)
Equipment Share of Liquid Fuel Use Scope 1 Emissions	Off-highway Haul Trucks	%	47.46	McPhee Creek Iron Ore Mine; Greenhouse Gas Assessment (2022)
	Excavator		18.60	
	Ancillary Equipment		14.48	
	Drilling and Blasting Equipment		12.67	
	Generator		2.39	
Abatement share (2050) **Group 1**: off-highway haul trucks, excavators, drilling and blasting equipment. **Group 2**: Generators and ancillary equipment	Group 1 - ACCUs	%	30	Applied Cap limit.
	Group 2 - ACCUs	%	30	
	Group 1 – Electrification	%	0	Top: Assumed no viable electrification. Bottom: Where electrification occurs, it is in line with adoption rates for road transport from IEA.
	Group 2 – Electrification	%	75	
	Group 1 – LCLFs	%	100	Assumed to offer lower marginal cost decarbonisation then hydrogen derivatives. Feedstock limits apply within market clearing to limit supply.
	Group 2 - LCLFs	%	100	
	Group 1 - Hydrogen derivatives	%	100	Assumed to be the last option for decarbonisation.
	Group 2 - Hydrogen derivatives	%	100	

Central Case | Road freight sector assumptions

Figure A3-9: Road freight decarbonisation profiles (2024 to 2050) in Central Case, for rigid and articulated trucks

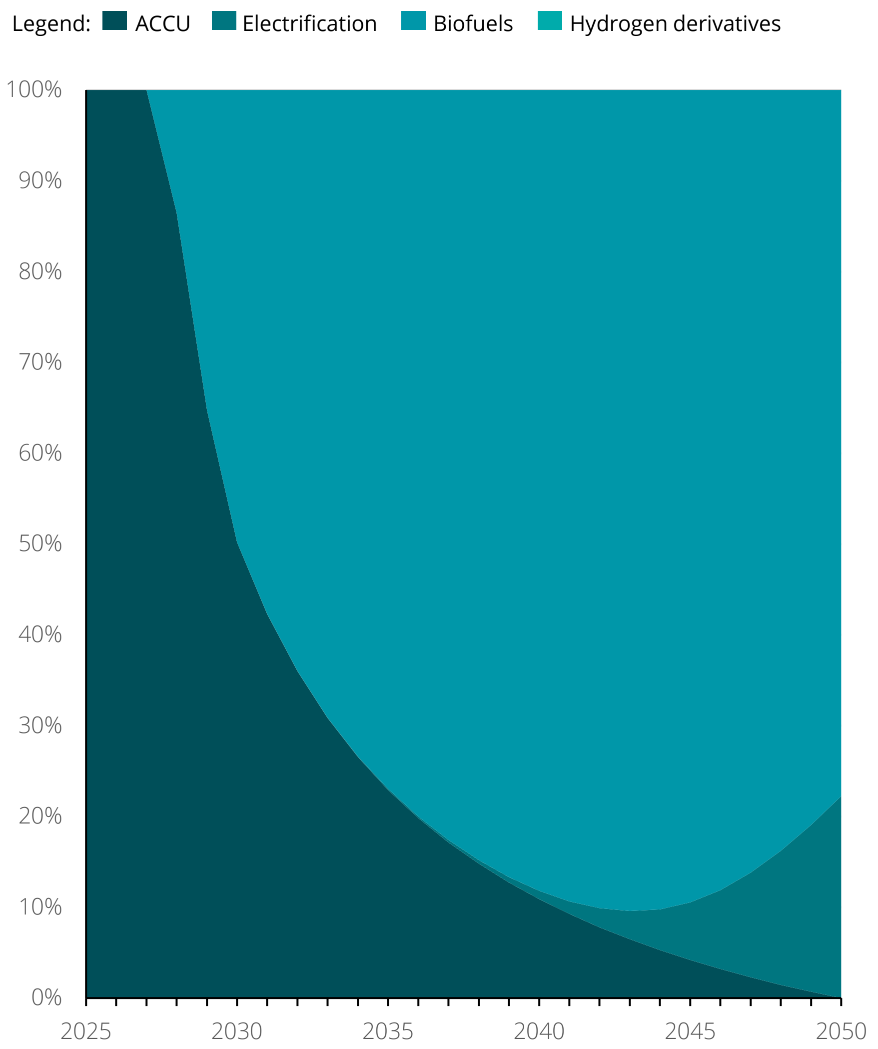


Table A3-5: Road Freight sector key assumptions and calculations

Assumption	Sub-assumption	Units	Quantum	Source
Sector Baseline Emissions		Mt CO_2-e	0.20	CER Safeguard Facility Reported Emissions Data (2022–23)
Sector Baseline Emissions Growth Rate		%	2.22	From NFDH; Road freight (2023)
Sector Baseline Emissions Adjustment for Efficiency		%	0.6	ABS; historical efficiency improvement.
Safeguard Mechanism abatement rate		% p.a.	4.9 (to 2030) 3.83 (2030 to 2050)	CER; Safeguard baselines (2024)
Liquid fuel use share of scope 1 emissions		%	95.40	Toll Sustainability Report (2023)
Equipment Share of Liquid Fuel Use Scope 1 Emissions		%	Articulated Trucks: 66 Rigid Trucks: 33	ABS Survey of Motor Vehicles
Abatement share (2050)	ACCUs	%	30	Applied Cap limit.
	Electrification	%	75	Assumed linear build to 75% by 2050. Where electrification occurs, it is in line with adoption rates for road transport from IEA.
	LCLFs	%	100	Assumed to offer lower marginal cost decarbonisation then hydrogen derivatives. Feedstock limits apply within market clearing to limit supply.
	Hydrogen derivatives	%	100	Assumed to be the last option for decarbonisation.

Central Case | Road freight sector assumptions

Figure A3-10: Coastal vessel decarbonisation profiles (2024 to 2050) in Central Case, coastal vessels

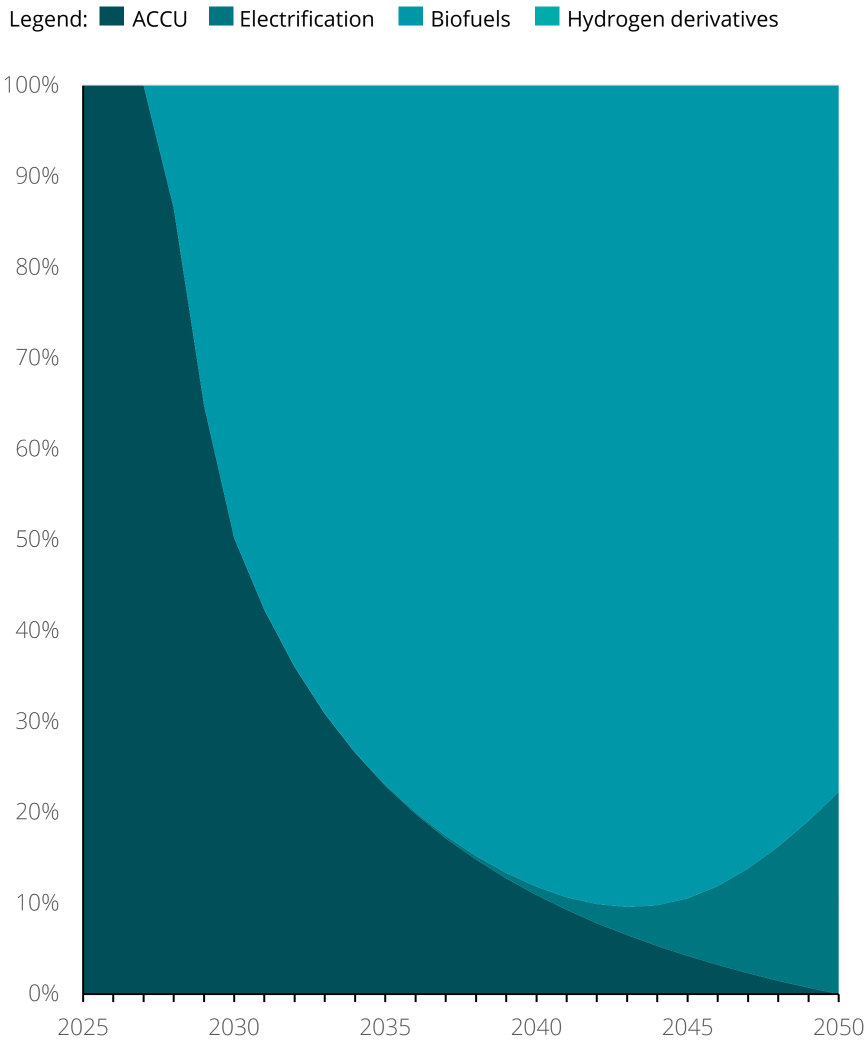


Table A3-6: Maritime sector key assumptions and calculations

Assumption	Sub-assumption	Units	Quantum	Source
Sector Baseline Emissions		Mt CO_2-e	0.20	CER Safeguard Facility Reported Emissions Data (2022–23)
Sector Baseline Emissions Growth Rate		%	2.22	From NFDH; Road freight (2023)
Sector Baseline Emissions Adjustment for Efficiency		%	0.6	ABS; historical efficiency improvement.
Safeguard Mechanism abatement rate		% p.a.	4.9 (to 2030) 3.83 (2030 to 2050)	CER; Safeguard baselines (2024)
Liquid fuel use share of scope 1 emissions		%	95.40	Toll Sustainability Report (2023)
Equipment Share of Liquid Fuel Use Scope 1 Emissions		%	Articulated Trucks: 66 Rigid Trucks: 33	ABS Survey of Motor Vehicles
Abatement share (2050)	ACCUs	%	30	Applied Cap limit.
	Electrification	%	75	Assumed linear build to 75% by 2050. Where electrification occurs, it is in line with adoption rates for road transport from IEA.
	LCLFs	%	100	Assumed to offer lower marginal cost decarbonisation then hydrogen derivatives. Feedstock limits apply within market clearing to limit supply.
	Hydrogen derivatives	%	100	Assumed to be the last option for decarbonisation.

Appendix A4: Accelerated Case Demand Scenario

Accelerated Case | Introduction

The Accelerated Case adopts the mechanics of the EU's aviation and maritime mandates to build demand for domestic aviation and maritime, while maintaining the demand profiles of the central scenario across the remaining sectors.

The ReFuelEU aviation initiative mandates that fuel producers provide a minimum share of biogenic SAF from 2025 and synthetic fuel from 2030 to EU aircraft operators. Fuel suppliers will have to incorporate two per cent SAF in 2025, 20 per cent in 2035 and 70 per cent in 2050. From 2030, the synthetic sub mandate regulates that all EU airports ensure 1.2 per cent of aviation fuels must also be synthetic fuels, rising to 35 per cent in 2050.

The FuelEU Maritime Regulation adopts a series of progressive emissions reduction targets to drive uptake of RD and hydrogen derived fuels. The regulation will oblige vessels to reduce the greenhouse gas intensity of the energy used on board by two per cent in 2025, 14.5 per cent in 2035 and 80 per cent in 2050 (compared to the average in 2020).

Within both mandates, multipliers also incentivise the early uptake of of advanced biofuels and Renewable Fuels of Non-Biological Origin (RFNBOs). ReFuelEU applies a 1.2x multiplier for advanced biofuels and 1.5x multiplier for RFNBOs to 2035, which allows fuel producers to meet uplift targets with greater ease. The FuelEU Maritime Regulation applies a multiplier of two to RFNBOs pre-2035, which means every tonne of RFNBO used by a company in fuelling its fleet will count twice towards the organisation's emissions reduction targets.[4]

Figure A4-1: ReFuelEU aviation mandate & synthetic sub mandate to 2050[1,2]

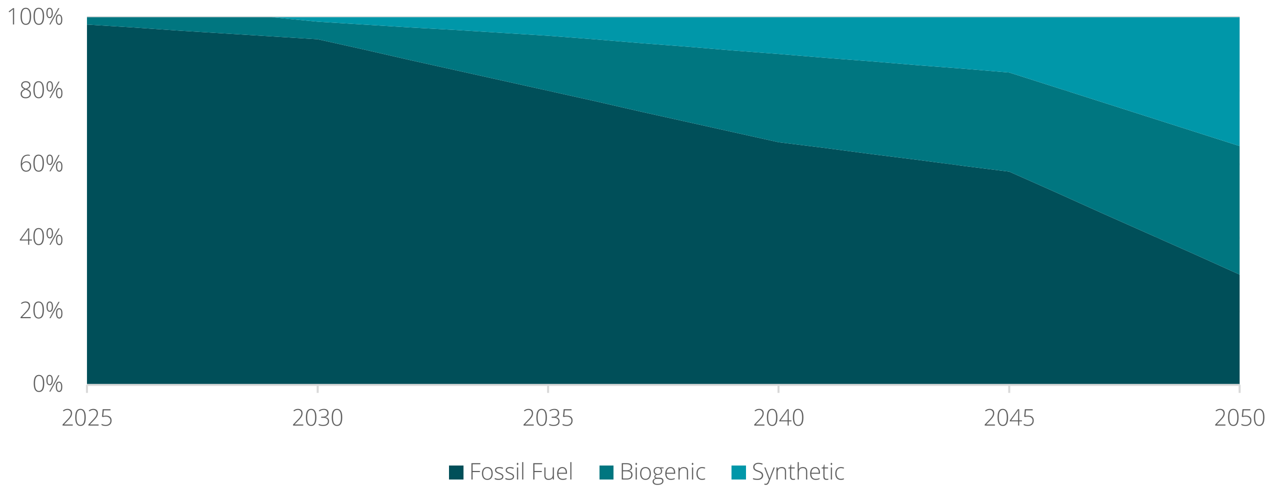
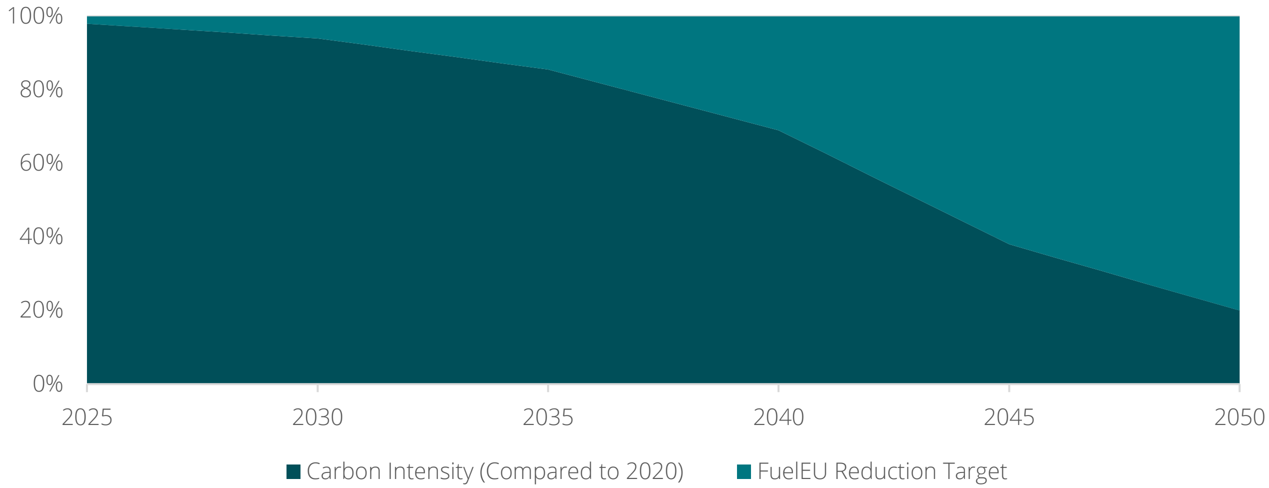


Figure A4-2: FuelEU maritime regulation carbon intensity reduction to 2050[3]



Sources: 1. RefuelEU aviation initiative: Council adopts new law to decarbonise the aviation sector, (2023). 2. Disentangling ReFuelEU: How will it shape the SAF market?, (2023). 3. Decarbonising maritime transport – FuelEU Maritime, 2023. 4. FuelEU Maritime Series – Part 5: RFNBOs, OPS and Penalties, (2024).

Accelerated Case | Calculations

Figure A4-3: Accelerated Case aviation demand calculation

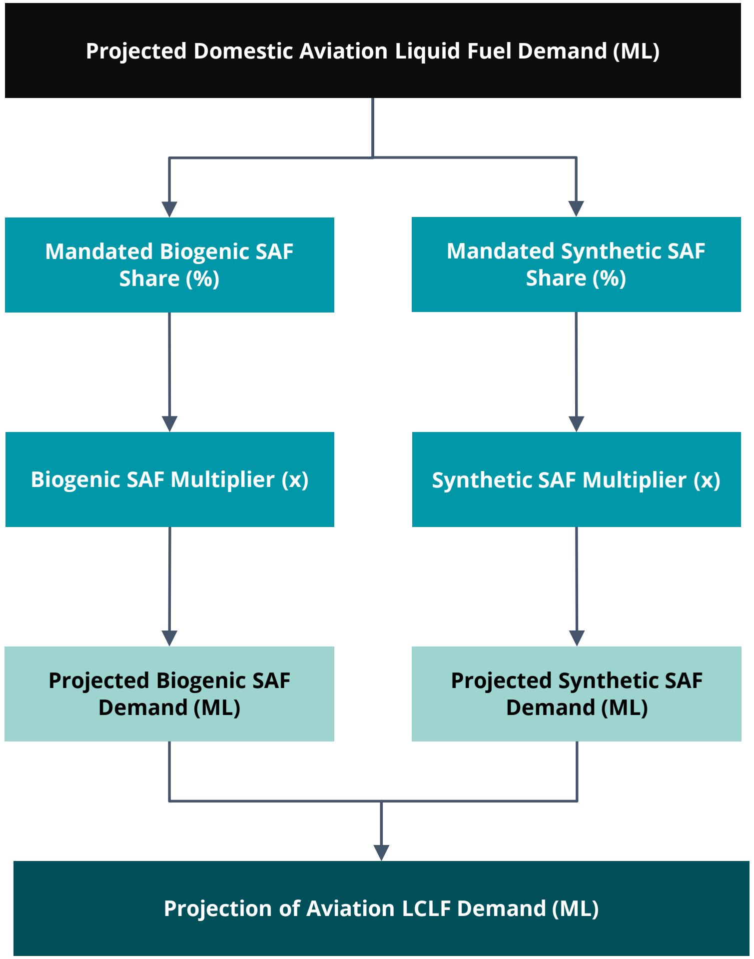


Table A4-1: Aviation sector key assumptions and calculations

Assumption	Units	Quantum	Source
Introduction of an EU SAF mandate	%	Mandate volume: 2% (2025), 6% (2030), 20% (2035), 34% (2040), 42% (2045) and 70% (2050) Synthetic Sub-Mandate: 1.2% (2030), 5% (2035), 10% (2040), 15% (2045) and 35% (2050)	The Council of the European Union (2023) SKYNRG (2023) Linear growth between available dates is assumed.
Biogenic multiplier	Factor	1.2 (2025 to 34) 1 (2035 to 50)	European Parliament (2023) Multiplier is assumed to be removed in 2035.
RFNBO multiplier	Factor	1.5 (2025 to 34) 1 (2035 to 50)	Transport and Environment (2023) Multiplier is assumed to be removed in 2035.

Accelerated Case | Calculations

Figure A4-4: Accelerated Case maritime demand calculation

Projected Domestic Maritime Liquid Fuel Demand (ML)

↓

Projected Domestic Maritime Emissions from Liquid Fuels (tCO_2-e)

↓

ReFuelEU GHG Intensity Reduction (%)

↓

RFNBO Multiplier (x)

↓

Projection of Aviation LCLF Demand (ML)

Table A4-2: Maritime sector key assumptions and calculations

Assumption	Units	Quantum	Source
Introduction of an EU maritime mandate	%	Mandated carbon intensity reduction: 2% (2025), 6% (2030), 14.5% (2035), 31% (2040), 62% (2045) and 80% (2050)	European Commission (2023) Linear growth between available dates is assumed.
RFNBO multiplier	Factor	2 (2025 to 34) 1 (2035 to 50)	European Union (2023) Multiplier is assumed to be removed in 2035.
Global shipping efficiency factor	%	CAGR (2020 to 2050) -0.92	IMO; Fourth Greenhouse Gas Study 2020 (2020)

Appendix B: Supply Analysis

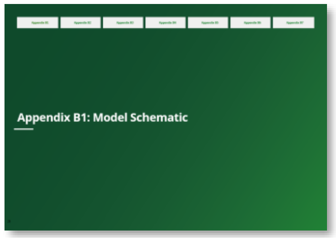
Appendix B | Supply Appendix Overview

Supply-side potential was assessed by technology and feedstock.18 technology/feedstock combinations were assessed in several permutations of industry evolution. A production model was required with flexibility to test scenarios, detailed in the following pages.

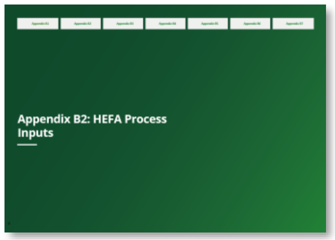
Appendix B sets out the LCLF production cost model schematic in how inputs and assumptions feed into outputs. Subsequent subsections present emissions intensities, physical and financial inputs unique to each of the four technologies and feedstocks studied within each. Core model assumptions were validated with key stakeholders.

Two core cost scenarios were constructed to represent a current trajectory and an optimistic trajectory and are presented in Appendix B6. These allow sensitivity of market response to be assessed. Broadly, the optimistic trajectory assumes significantly larger and more efficient plant to represent economies of scale. Feedstock price is also assumed to grow at a slower rate in the optimistic trajectory scenario as producer competition increases in response to stronger demand signals. These scenarios are detailed in the overall scenario table in the scenario analysis chapter.

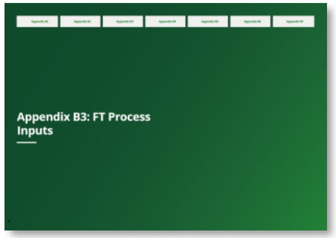
This technical appendix outlines the key assumptions for both cases, provides a sensitivity analysis of costs and concludes with detail on the process driving marginal abatement cost rankings.



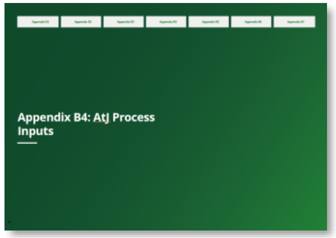
Details the mechanisms through which the production cost model assesses the selected technology and feedstock combinations across modelled market scenarios.



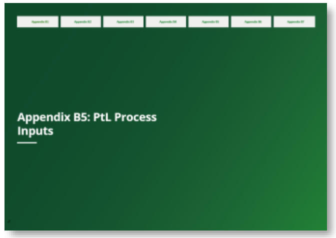
Sets out detail on the five HEFA feedstocks considered, including emissions intensities, physical and financial inputs. Assumptions regarding feedstock cost breakdown and growth rates are provided.



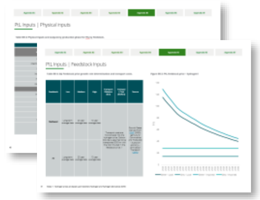
Sets out detail on the five FT feedstocks considered, including emissions intensities, physical and financial inputs. Assumptions regarding feedstock cost breakdown and growth rates are provided.

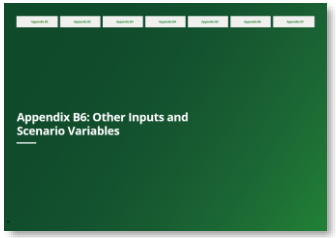


Sets out detail on the six AtJ feedstocks considered, including emissions intensities, physical and financial inputs. Assumptions regarding feedstock cost breakdown and growth rates are provided.

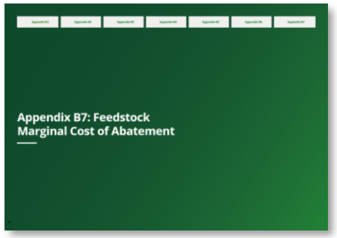


Sets out detail on the two PtL feedstocks considered, including emissions intensities, physical and financial inputs. Assumptions regarding feedstock cost breakdown and growth rates are provided.





Includes detail on other financial inputs relevant to the production process and key scenario variables specified under each market trajectory. SAF prices under each scenario are provided.



Provides detail on criteria and weightings used as inputs to assess each feedstock/fuel production pathway and subsequent assessment outputs.

Appendix B1: Model Schematic

Model Schematic | Cost model overview

Forming a productive understanding of how Australia's LCLF supply potential could evolve over time requires assessment across a wide array of:

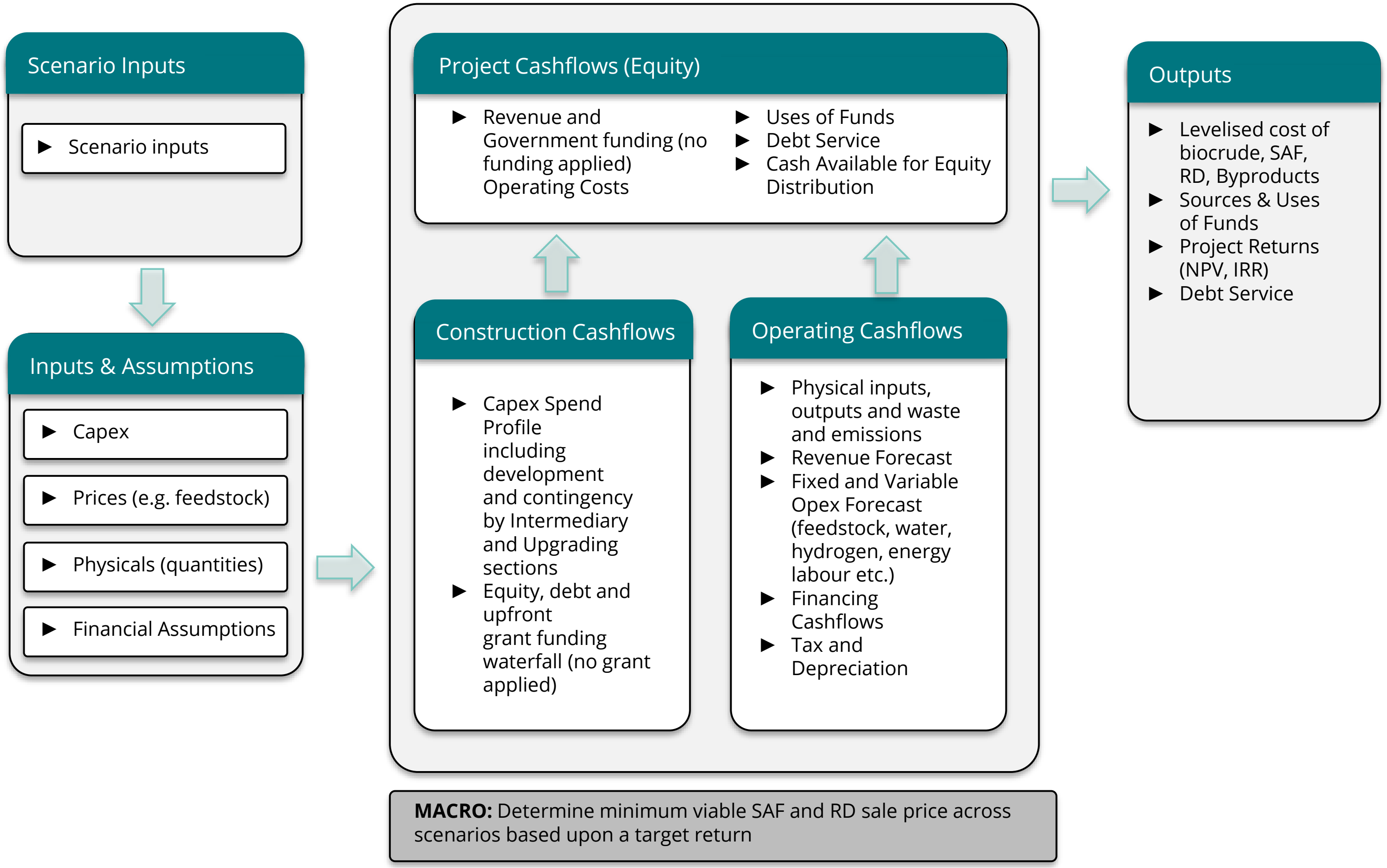
- Production technology and feedstock combinations; and
- Production and market evolution permutations.

As part of this market study, a production cost model was developed with the ability to test these potential scale-up pathways (see Figure B1-1). The model develops supply costs for 18 technology–feedstock combinations across HEFA, AtJ, FT, and PtL processes. For each technology–feedstock combination, the model also offers flexibility to test a range of indicative market permutations relating to physical inputs, financial inputs, plant capacity, supply chain configurations and feedstock price/growth rates.

This assessment takes into account the best available market information. The key assumptions underpinning the production model have been validated, where applicable, with a range of current project developers

For the purposes of the study, two core cost scenarios have been developed, applying sensitivities to the market evolution permutations to present a current and optimistic trajectory for future LCLF supply costs. This technical appendix outlines the key assumptions for both scenarios.

Figure B1-1: Schematic of LCLF Production Cost Model



Appendix B2: HEFA Process Inputs

HEFA Inputs | Emissions intensities

The cost model and feedstock market model considers five feedstocks fed into the HEFA pathway:

- Tallow
- Used Cooking Oil
- Canola
- Cotton seed
- Other Oilseeds (Carinata)

The HEFA configuration assumes an upgrading step only, with feedstocks assumed to arrive at the plant gate pre-treated and prepared for upgrading. As such, oilseed prices and the underlying physical inputs reflect oil-based form being upgraded to fuel.

The prices determined reflect the approximate market price (separated into harvest, transport and opportunity cost). Lack of price transparency for a given feedstocks such as Australian tallow and used cooking oil are a limitation of this work and would alter the end fuel price.

Table B2-1: Emissions intensities by HEFA feedstock.

Description	Units	Quantum	Source
Tallow	tCO_2-e / t feedstock	0.295	ICAO; ICAO-GREET Model (2019)
Used cooking oil	tCO_2-e / t feedstock	0.631	ICAO; ICAO-GREET Model (2019)
Canola	tCO_2-e / t feedstock	0.630	ICAO; ICAO-GREET Model (2019)
Cotton Seed	tCO_2-e / t feedstock	0.627	ICAO; ICAO-GREET Model (2019)
Other oilseeds (carinata)	tCO_2-e / t feedstock	0.445	ICAO; ICAO-GREET Model (2019)

HEFA Inputs | Physicals

Table B2-2: Physical inputs and outputs by plant phase and feedstock for HEFA.

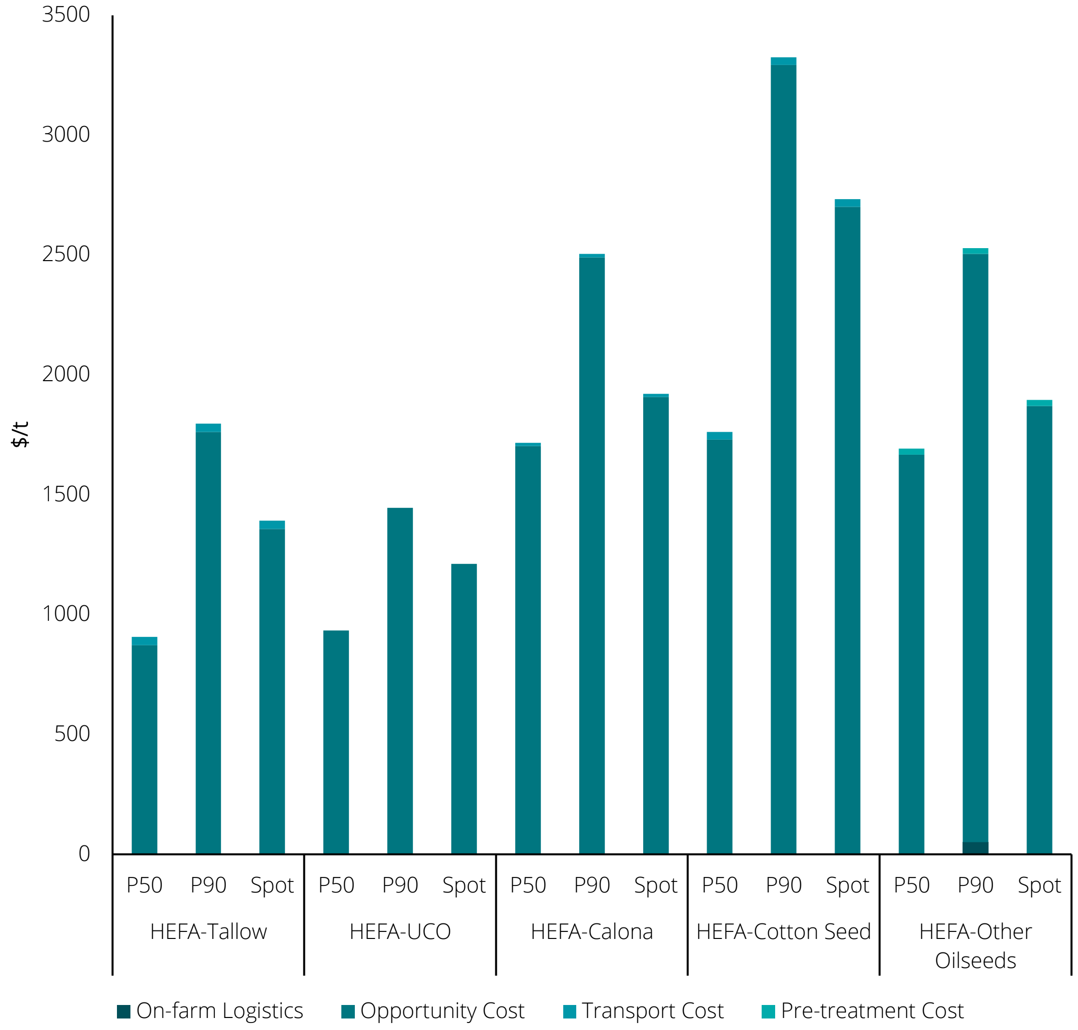
Assumption	Units	HEFA – Tallow	HEFA – Used Cooking Oil	HEFA – Canola	HEFA – Cotton Seed	HEFA – Other Oil Seeds (Carinata)
Intermediate Plant						
Feedstock Inputs	t/t feedstock	1.00	1.00	1.00	1.00	1.00
Intermediate Outputs	t/t feedstock	1.00	1.00	1.00	1.00	1.00
Upgrading Plant						
Intermediate Inputs	t /t intermediate	1.00	1.00	1.00	1.00	1.00
Hydrogen Inputs	GJ/t intermediate	4.20	4.80	3.18	3.18	3.18
Electricity Inputs	MWh/t intermediate	0.05	0.05	0.04	0.04	0.04
Natural Gas Inputs	GJ/t intermediate	3.00	3.00	2.83	2.83	2.83
SAF Outputs	GJ/t intermediate	21.24	21.24	33.80	33.80	33.80
RD Outputs	GJ/t intermediate	10.49	10.49			
Naphtha Outputs	GJ/t intermediate	4.81	4.81	0.87	0.87	0.87
Propane Outputs	GJ/t intermediate	5.03	5.03	2.90	2.90	2.90
Source		Garcilasso (2014) and Pearlson et al., (2013)	Garcilasso (2014) and Pearlson et al., (2013)	ICAO; ICAO-GREET Model (2019)	ICAO; ICAO-GREET Model (2019)	ICAO; ICAO-GREET Model (2019)

HEFA Inputs | Financial inputs

Table B2-3: Capital and operating cost inputs for HEFA.

Variable	Sub-Variable	Units	Value	Source
Capex	Intermediate	$/t feedstock	-	-
	Upgrading	$/t intermediate	$1,848	Bloomberg project tracker
Capex Rate		% per annum	-0.6%	WEF
Capex Multiplier	Pioneer	Multiplier	1	ICAO
	Nth Facility	Multiplier	1	ICAO
Fixed Opex	Other	% capex	2%	Santos, C et al., (2018)
	Overhead	% capex	2%	RSB (2024), *Report on the Techno-Economic Assessment of SAF Pathways*
	Maintenance	% capex	2%	Santos, C et al., (2018)
	Labour Cost	% capex	3%	Santos, C et al., (2018)

Figure B2-1: HEFA feedstock cost inputs[1,2]



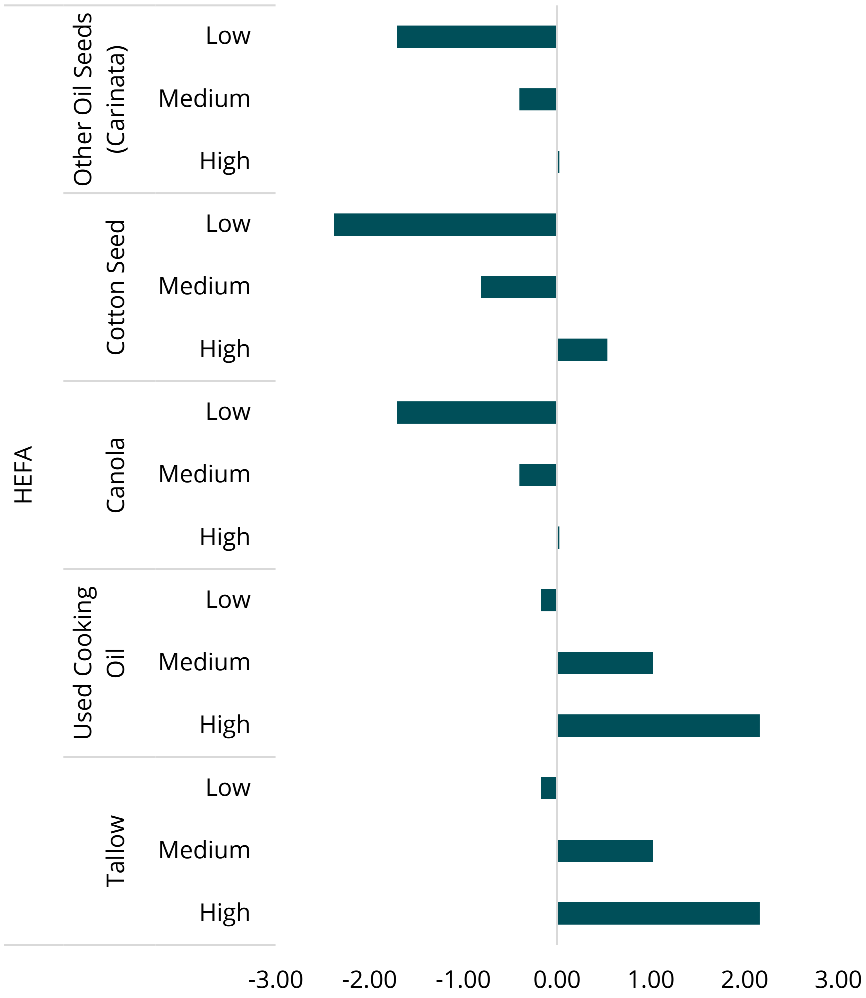
Notes: 1. P50 and P90 determined from historical timeseries associated with the opportunity cost. Tallow – Opportunity Cost - MLA |, UCO – Opportunity Cost - NARA, Canola – Opportunity Cost - DAFF, Cotton Seed – Opportunity Cost - USDA, Other Oilseeds (Carinata) – assumed to align with canola. 2. Transport costs are developed from CSIRO TraNSIT.

HEFA Inputs | Feedstock inputs

Table B2-4: HEFA feedstock price growth rate determination and transport costs.

Feedstock	Low	Medium	High	Transport Distance (km)	Transport Cost ($/t/km)	Source
HEFA – Tallow	Long-term average data	20 year average data	10 year average data	200	0.23	Growth Rates: MLA (2025) *Market Statistics – Rendered Products* Transport: CSIRO
HEFA – Used Cooking Oil	Long-term average data	20 year average data	10 year average data	15	0.16	NARA (2023), *US Market Report* Transport: CSIRO
HEFA – Canola	Long-term average data	10 year average data	20 year average data	140	0.15	Derived from DAFF (2023). *Agricultural Commodities and Trade data – Australian economy – farm sector* Transport: CSIRO
HEFA – Cotton Seed	Long-term average data	20 year average data	10 year average data	198	0.22	
HEFA – Other Oil Seeds (Carinata)	Long-term average data	10 year average data	20 year average data	16	0.18	

Figure B2-2: HEFA feedstock price growth rates (%)



Appendix B3: FT Process Inputs

FT Inputs | Emissions intensities

The cost model and feedstock market model considers five feedstocks fed into the FT pathway:

- Bagasse
- Municipal Solid Waste
- Agricultural Residues (Wheat Straw)
- Sawmill Residues
- Oil Mallee Residues

The FT configuration assumes an intermediate step, whereby feedstock is transformed into bio-oil, followed by an upgrading step to the fuel product slate. Feedstocks are assumed to enter the intermediate step pre-treated, with the treatment cost included within the feedstock cost.

The prices determined reflect the approximate market price (separated into harvest, transport and opportunity cost). Where waste feedstocks have been utilised, the feedstock price has been estimated based upon the opportunity cost revenue for the feedstock. For Bagasse this is assumed to be electricity generation. For Municipal solid waste this is a saving, associated with not paying the waste disposal levy. This is assumed to be standard nationally but empirically will vary across states. For agricultural residues there is assumed to be no opportunity cost. For sawmill residues and oil mallee residues the opportunity cost is assumed to align with the export price of wood chips.

Table B3-1: Emissions intensities by FT feedstock and energy source.

Description	Units	Quantum	Source
Bagasse	tCO_2-e / t feedstock	0.030	ICAO; ICAO-GREET Model (2019)
Municipal solid waste	tCO_2-e / t feedstock	0.013	ICAO; ICAO-GREET Model (2019)
Agricultural residues	tCO_2-e / t feedstock	0.01334	ICAO; ICAO-GREET Model (2019)
Sawmill residues	tCO_2-e / t feedstock	0.021	ICAO; ICAO-GREET Model (2019)
Oil mallee residues	tCO_2-e / t feedstock	0.009	ICAO; ICAO-GREET Model (2019)

FT Inputs | Physical inputs – intermediate plant

Table B3-2: Physical inputs and outputs for an intermediate plant for FT by feedstock.

Assumption	Units	FT – Bagasse	FT – Municipal Solid Waste	FT – Agricultural Residues	FT – Sawmill Residues	FT – Oil Mallee Residues
Intermediate Plant						
Feedstock Inputs	t/t feedstock	1.00	1.00	1.00	1.00	1.00
Electricity Input – No Generation	MWh/t feedstock	0.58	0.58	0.58	0.58	0.58
Natural Gas Inputs	GJ/t feedstock	-	0.33	-	-	-
Potable Water Inputs	L/t feedstock	219.34	219.34	219.34	219.34	219.34
Air Inputs	t/t feedstock	0.05	0.05	0.05	0.05	0.05
Diethanolamine Inputs	t/t feedstock	0.00	0.00	0.00	0.00	0.00
Oxygen Inputs	t/t feedstock	0.41	0.74	0.41	0.41	0.41
Intermediate Outputs	t/t feedstock	0.17	0.23	0.23	0.23	0.23
Ash Outputs	t/t feedstock	0.01	0.08	0.01	0.01	0.01
Electricity Outputs – Export	MWh/t feedstock	0.19	0.19	0.19	0.19	0.19
Hydrogen Outputs	GJ/t feedstock	6.00	6.00	6.00	6.00	6.00
Water Waste Outputs	t/t feedstock	0.22	0.22	0.22	0.22	0.22
Waste Gases Outputs	t/t feedstock	1.16	1.24	1.16	1.16	1.16
Source		MDPI; FT Synthesis Integrated to Sugarcane Biorefineries (2020)	EXP; MSW to Liquid Fuels (2023)	MDPI; FT Synthesis Integrated to Sugarcane Biorefineries (2020) RSC; SAF Production from Forest Residue (2024)	MDPI; FT Synthesis Integrated to Sugarcane Biorefineries (2020) RSC; SAF Production from Forest Residue (2024)	MDPI; FT Synthesis Integrated to Sugarcane Biorefineries (2020) RSC; SAF Production from Forest Residue (2024)

FT Inputs | Physical inputs – upgrading plant

Table B3-3: Physical inputs and outputs for an upgrading plant for FT by feedstock.

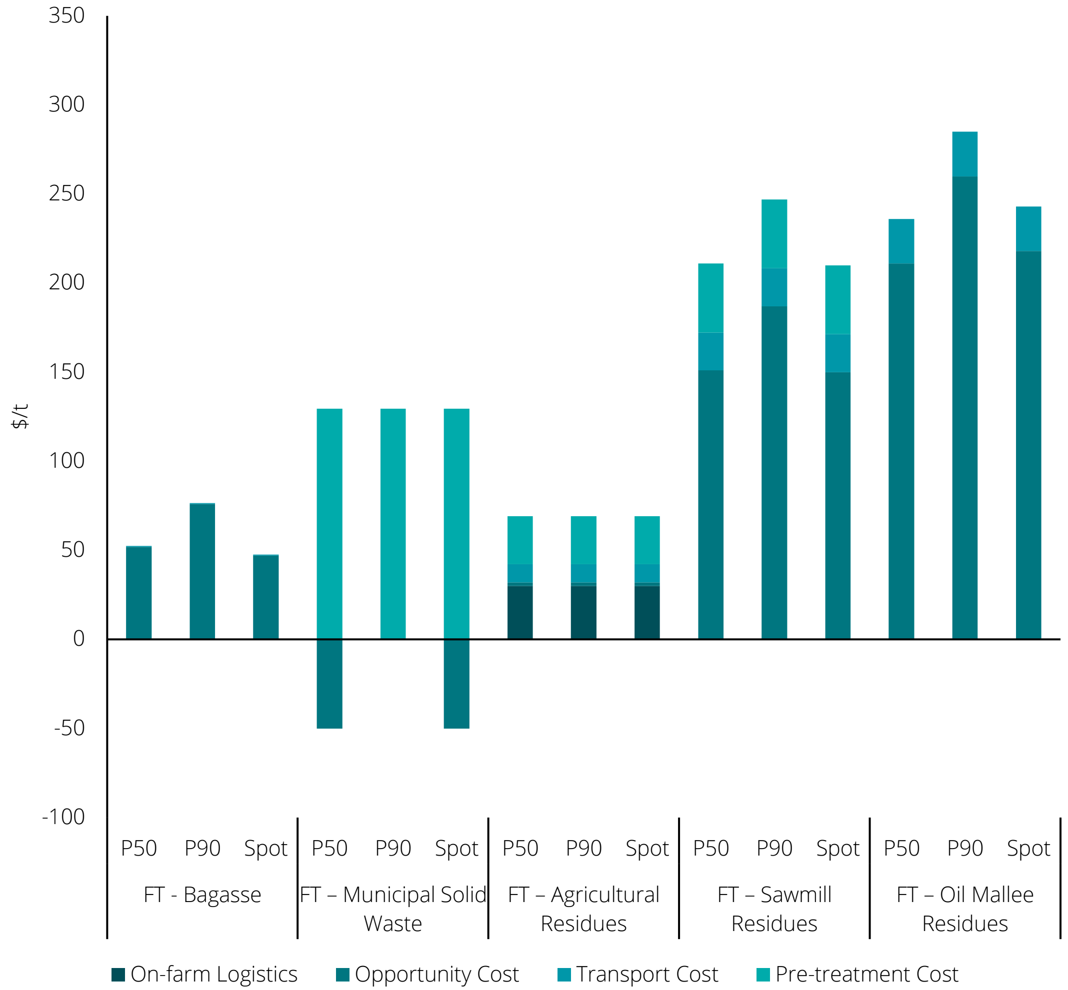
Assumption	Units	FT – Bagasse	FT – Municipal Solid Waste	FT – Agricultural Residues	FT – Sawmill Residues	FT – Oil Mallee Residues
Upgrading Plant						
Intermediate Inputs	t /t intermediate	1.00	1.00	1.00	1.00	1.00
Electricity Inputs	MWh/t intermediate	0.15	0.15	0.15	0.15	0.15
Hydrogen Inputs	GJ/t intermediate	6.00	6.00	6.00	6.00	6.00
SAF Outputs	GJ/t intermediate	17.98	17.98	17.98	17.98	17.98
RD Outputs	GJ/t intermediate	4.63	4.63	4.63	4.63	4.63
Electricity Outputs – Export	MWh/t intermediate	0.19	0.19	0.19	0.19	0.19
Wastewater Outputs	L/t intermediate product	0.01	0.01	0.01	0.01	0.01
Waste Gases Outputs	t/t intermediate	0.24	0.24	0.24	0.24	0.24
Source		MDPI; FT Synthesis Integrated to Sugarcane Biorefineries (2020)	MDPI; FT Synthesis Integrated to Sugarcane Biorefineries (2020)	MDPI; FT Synthesis Integrated to Sugarcane Biorefineries (2020)	MDPI; FT Synthesis Integrated to Sugarcane Biorefineries (2020)	MDPI; FT Synthesis Integrated to Sugarcane Biorefineries (2020)

FT Inputs | Financial inputs

Table B3-4: Capital and operating cost inputs for FT.

Variable	Sub-Variable	Units	Value	Source
Capex	Intermediate	$/t feedstock	$1,135	Bloomberg project tracker
	Upgrading	$/t intermediate	$2,094	Bloomberg project tracker
Capex Rate		% per annum	-1.0%	WEF
Capex Multiplier	Pioneer	Multiplier	1.17	US Department of Energy
	Nth Facility	Multiplier	1	US Department of Energy
Fixed Opex	Other	% capex	2%	Santos, C et al., (2018)
	Overhead	% capex	2%	RSB (2024), *Report on the Techno-Economic Assessment of SAF Pathways*
	Maintenance	% capex	2%	Santos, C et al., (2018)
	Labour Cost	% capex	3%	Santos, C et al., (2018)

Figure B3-1: FT feedstock cost inputs[1,2]



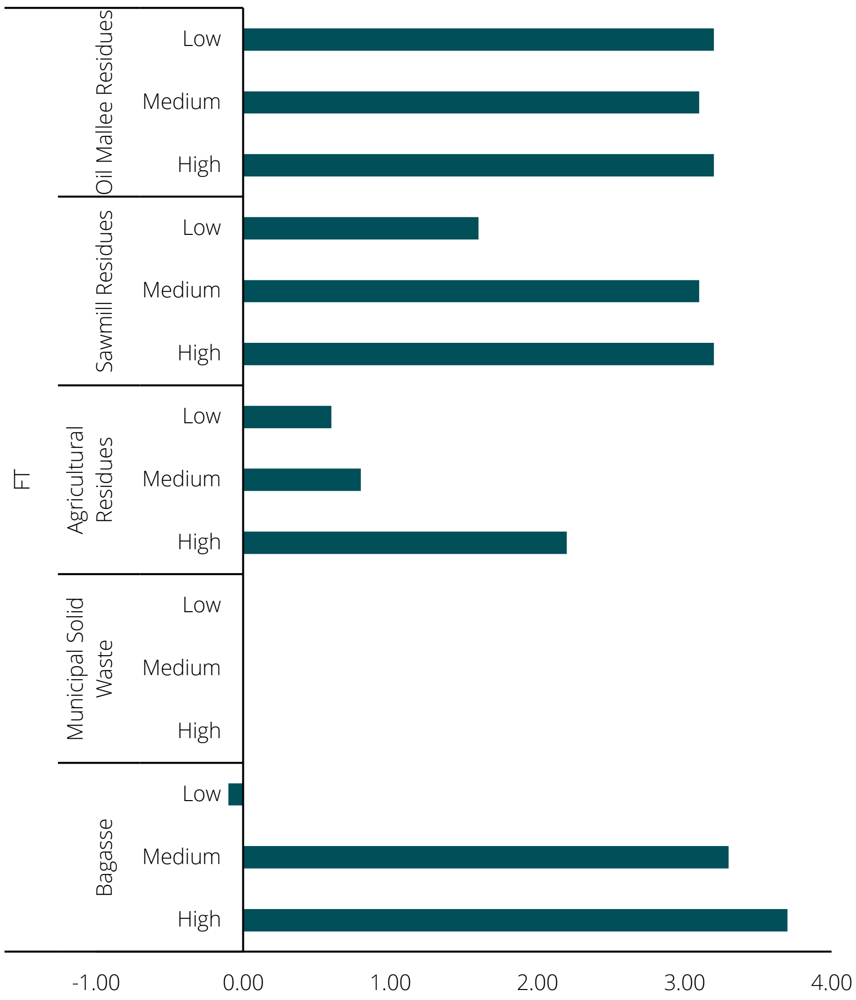
Notes: 1. P50 and P90 determined from historical timeseries associated with the opportunity cost. Bagasse – Opportunity Cost - based upon wholesale electricity price estimates, Municipal Solid Waste – Opportunity Cost – assumed levy share of $50 in the P50 case and $0/t in the P90 case | Pre-treatment Cost – CLARA inclusive of sorting and pre-treatment, Agricultural Residues – On-farm Logistics – Canadian Government| Pre-treatment Cost - CLARA, Sawmill Residues – Opportunity Cost - DAFF | Pre-treatment Cost - CLARA , Oil Mallee Residues – DAFF. 2. Transport costs are developed from CSIRO TraNSIT.

FT Inputs | Feedstock inputs

Table B3-5: FT Feedstock price growth rate determination and transport costs.

Feedstock	Low	Medium	High	Transport Distance (km)	Transport Cost ($/t/km)	Source
Bagasse	Long-term average data	20 year average data	10 year average data	55.1	0.11	Growth Rates: Derived from DAFF (2023). *Agricultural Commodities and Trade data – Australian economy – farm sector* Transport: CSIRO
Municipal Solid Waste	Waste levy grows in line with the CPI	Waste levy grows in line with the CPI	Waste levy grows in line with the CPI	15.8	0.81	DCCEEW (2022), *National Waste Reports* Transport: CSIRO
Agricultural Residues	Long-term average data	10 year average data	20 year average data	142	0.11	Derived from DAFF (2023). *Agricultural Commodities and Trade data – Australian economy – farm sector* Transport: CSIRO
Sawmill Residues	Long-term average data	20 year average data	10 year average data	143	0.23	
Oil Mallee Residues	Assumed in line with sawmill residues	Assumed in line with sawmill residues	Assumed in line with sawmill residues	300	0.10	

Figure B3-2: FT feedstock price growth rates (%)



Appendix B4: AtJ Process Inputs

AtJ Inputs | Emissions intensities

The cost model and feedstock market model considers six feedstocks fed into the AtJ pathway:

- Sugarcane
- Bagasse
- Sorghum
- Agricultural Residues
- Sawmill Residues
- Oil Mallee Residues.

The AtJ configuration assumes an intermediate step, whereby feedstock is transformed into ethanol, followed by an upgrading step to the fuel product slate. Feedstocks are assumed to enter the intermediate step pre-treated, with the treatment cost included within the feedstock cost.

The prices determined reflect the approximate market price (separated into harvest, transport and opportunity cost). Where waste feedstocks have been utilised, the feedstock price has been estimated based upon the opportunity cost revenue for the feedstock. For Bagasse this is assumed to be electricity generation. For agricultural residues there is assumed to be no opportunity cost. For sawmill residues and oil mallee residues the opportunity cost is assumed to align with the export price of wood chips.

Table B4-1: Emissions intensities by AtJ feedstock and energy source.

Description	Units	Quantum	Source
Sugarcane	tCO_2-e / t feedstock	0.021	ICAO; ICAO-GREET Model (2019)
Bagasse	tCO_2-e / t feedstock	0.031	
Sorghum	tCO_2-e / t feedstock	0.062	
Agricultural residues	tCO_2-e / t feedstock	0.018	
Sawmill residues	tCO_2-e / t feedstock	0.010	
Oil mallee residues	tCO_2-e / t feedstock	0.025	

AtJ Inputs | Physical inputs

Table B4-2: Physical inputs and outputs by production phase for AtJ by feedstock.

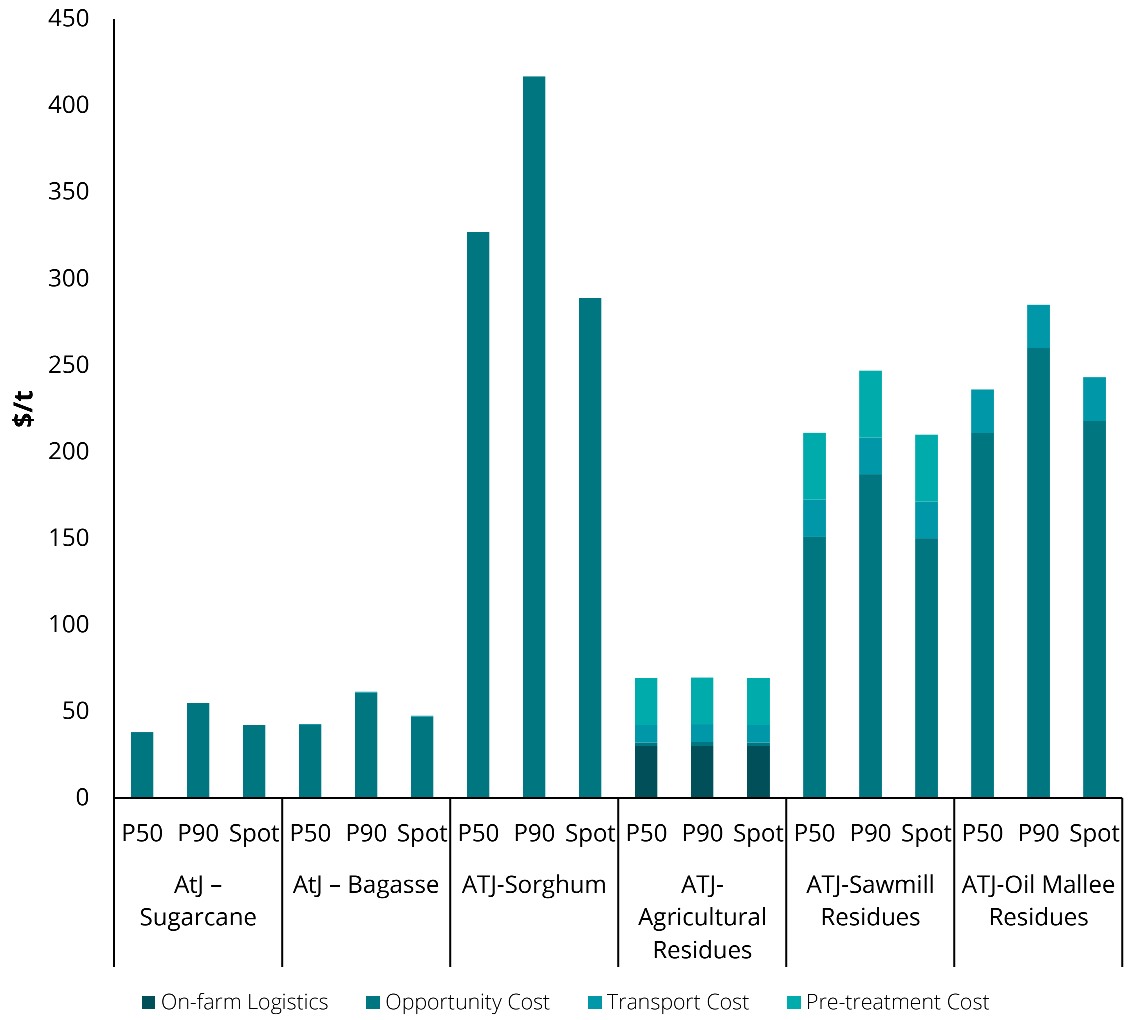
Assumption	Units	AtJ – Sugarcane	AtJ – Bagasse	AtJ – Sorghum	AtJ – Agricultural Residues	AtJ – Sawmill Residues	AtJ – Oil Mallee Residues
Intermediate Plant							
Feedstock Inputs	t/t feedstock	1.00	1.00	1.00	1.00	1.00	1.00
Electricity – No Generation	MWh/t feedstock	0.04	0.04	0.12	0.04	0.04	0.04
Natural Gas Inputs	GJ/t feedstock					0.32	0.32
Diesel Inputs	GJ/t feedstock			0.02	0.02	0.03	0.03
Potable Water Inputs	L/t feedstock	23,570	23,570	23,570	23,570	23,570	23,570
Steam Inputs	t/t feedstock	-	0.72				
Intermediate Outputs	t/t feedstock	0.06	0.03	0.28	0.09	0.09	0.09
Electricity Outputs – Export	MWh/t feedstock	0.13	0.18	0.13	0.22	0.22	0.22
Solid Landfill Waste Outputs	t/t feedstock		1.66	1.66			
Upgrading Plant							
Intermediate Inputs	t /t intermediate	1.00	1.00	1.00	1.00	1.00	1.00
Hydrogen Inputs	GJ/t intermediate	1.10	1.10	1.10	1.10	1.10	1.10
Electricity Inputs	MWh/t intermediate	0.17	0.14	0.17	0.17	0.17	0.17
Natural Gas Inputs	GJ/t intermediate		0.86	7.90			
Diesel Inputs	GJ/t intermediate		0.15	0.15			
Cooling Water Inputs	L/t intermediate		6,240	6,240			
SAF Outputs	GJ/t intermediate	15.18	22.49	15.18	15.18	15.18	15.18
RD Outputs	GJ/t intermediate	3.86	2.92	3.86	3.86	3.86	3.86
Naphtha Outputs	GJ/t intermediate	5.49	0.86	5.49	5.49	5.49	5.49
Heavy Fuel Oil Outputs	GJ/t intermediate	1.19		1.19	1.19	1.19	1.19
Propane Outputs	GJ/t intermediate		1.64				
Wastewater Outputs	L/t intermediate product		155.47	155.47			
Source		ICAO; ICAO-GREET Model (2019), Santos, C et al., Integrated first and second generation sugarcane bio-refinery for jet fuel production in Brazil (2018)					

AtJ Inputs | Financial inputs

Table B4-3: Capital and operating cost inputs for AtJ.

Variable	Sub-Variable	Units	Value	Source
Capex	Intermediate	$/t feedstock	Sucrose, Starch and Cellulosic dependent	Bloomberg project tracker
	Upgrading	$/t intermediate	$513	Bloomberg project tracker
Capex Rate		% per annum	-1.0%	WEF
Capex Multiplier	Pioneer	Multiplier	1.17	US Department of Energy
	Nth Facility	Multiplier	1	US Department of Energy
Fixed Opex	Other	% capex	2%	Santos, C et al., (2018)
	Overhead	% capex	2%	RSB (2024), *Report on the Techno-Economic Assessment of SAF Pathways*
	Maintenance	% capex	2%	Santos, C et al., (2018)
	Labour Cost	% capex	3%	Santos, C et al., (2018)

Figure B4-1: AtJ feedstock cost inputs[1,2]



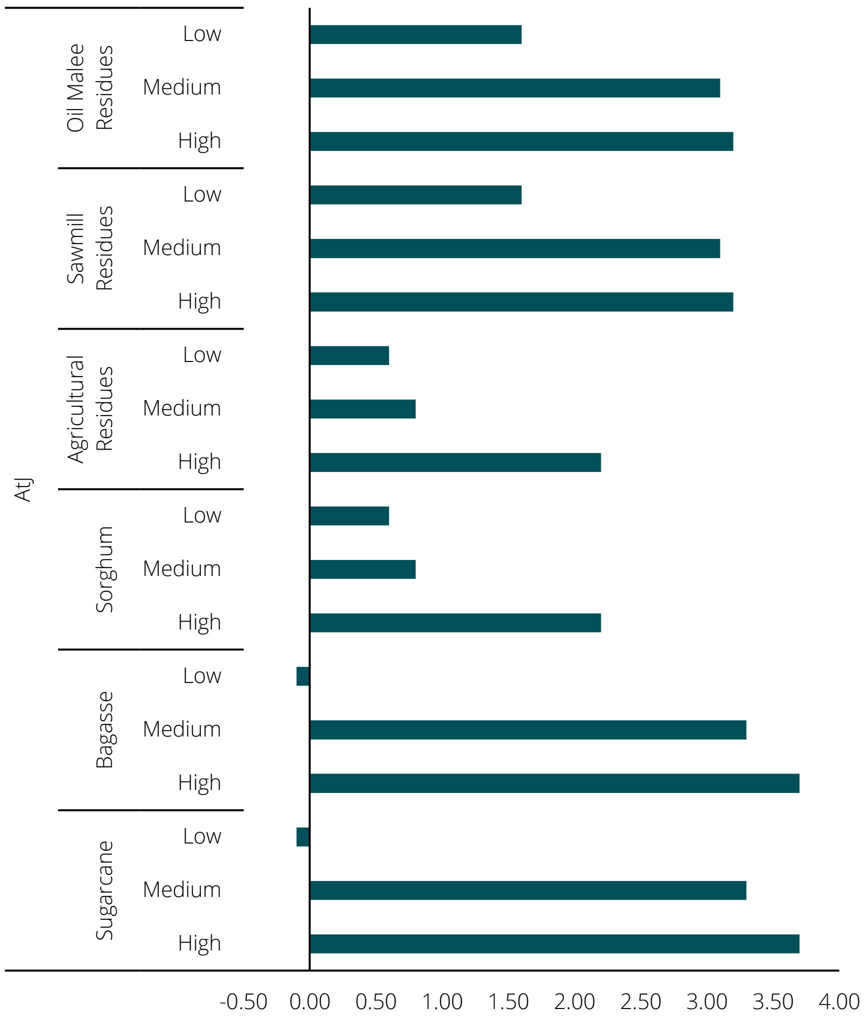
Notes: 1. P50 and P90 determined from historical timeseries associated with the opportunity cost. Sugarcane – Opportunity Cost - DAFF, Bagasse – Opportunity Cost - based upon wholesale electricity price estimates, Sorghum - DAFF, Agricultural Residues – On-farm Logistics – Canadian Government | Pre-treatment Cost - CLARA, Sawmill Residues – Opportunity Cost - DAFF | Pre-treatment Cost - CLARA , Oil Mallee Residues – DAFF. 2. Transport costs are developed from CSIRO TraNSIT.

AtJ Inputs | Feedstock inputs

Table B4-4: AtJ Feedstock price growth rate determination and transport costs.

Feedstock	Low	Medium	High	Transport Distance (km)	Transport Cost ($/t/km)	Source
Sugarcane	Long-term average data	20 year average data	10 year average data	20.5	0.26	Growth Rates: Derived from DAFF (2023). *Agricultural Commodities and Trade data - Australian economy – farm sector* Transport: CSIRO
Bagasse	Long-term average data	20 year average data	10 year average data	55.1	0.11	
Sorghum	Long-term average data	10 year average data	20 year average data	142	0.11	
Agricultural Residues	Long-term average data	10 year average data	20 year average data	142	0.11	
Sawmill Residues	Long-term average data	20 year average data	10 year average data	143	0.23	
Oil Mallee Residues	Assumed in line with sawmill residues	Assumed in line with sawmill residues	Assumed in line with sawmill residues	300	0.10	

Figure B4-2: AtJ feedstock price growth rates (%)



Appendix B5: PtL Process Inputs

PtL Inputs | Emissions intensities

The cost model and feedstock market model considers two PtL Pathways:

- Methanol synthesis
- FT production from syngas

The pathway configuration assumes an intermediate step, whereby feedstock is transformed into either methanol or bio-oil, followed by an upgrading step to the fuel product slate.

The hydrogen price represents the main cost driver, with green hydrogen assumed to be used. This is priced using Deloitte's GVCE Hydrogen and Hydrogen derivatives Cost Model.

Table B5-1: Emissions intensities by PtL feedstock and energy source.

Description	Units	Quantum	Source
PtL–Methanol	tCO_2-e / t feedstock	0.000	ICAO; ICAO-GREET Model (2019)
PtL–FT	tCO_2-e / t feedstock	0.000	ICAO; ICAO-GREET Model (2019)

PtL Inputs | Physical inputs

Table B5-2: Physical inputs and outputs by production phase for PtL by feedstock.

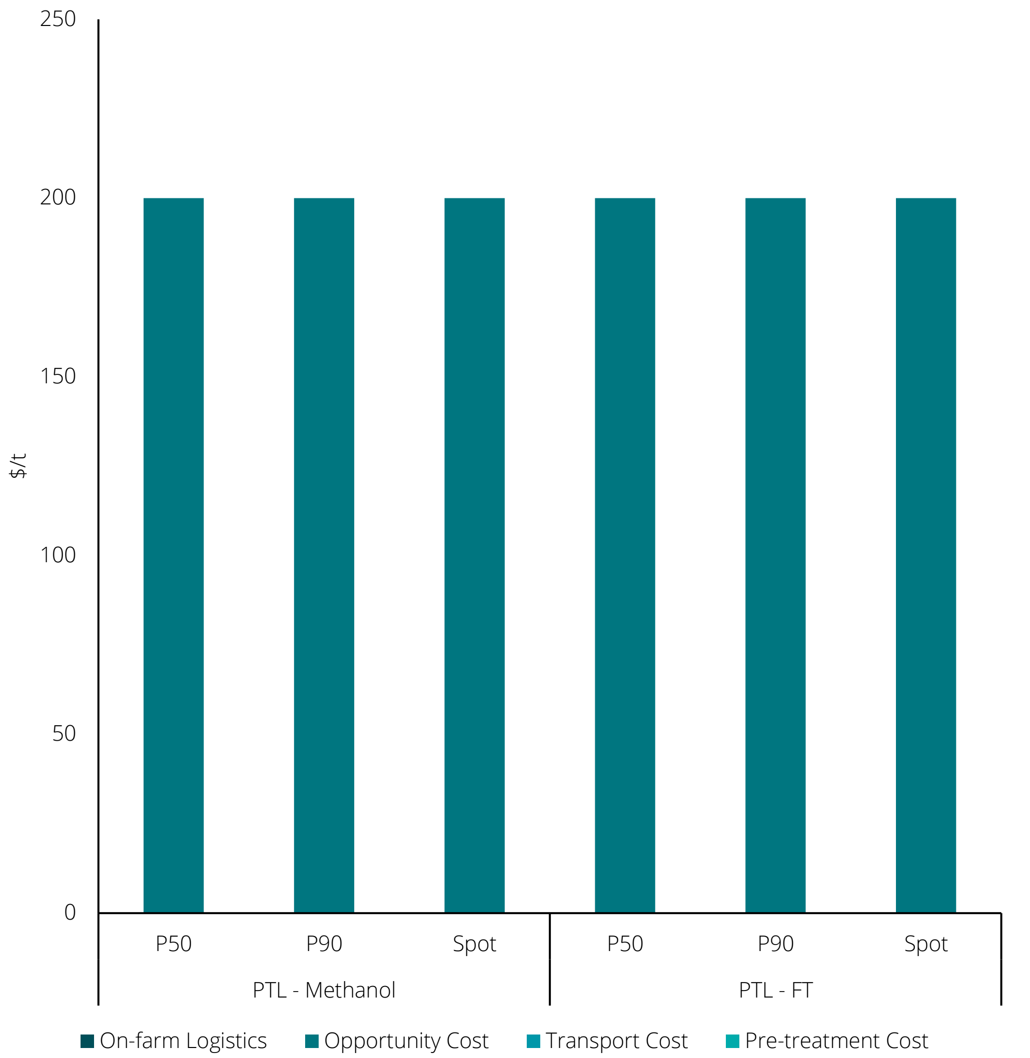
Assumption	Units	PtL – Methanol	PtL – FT
Intermediate Plant			
Feedstock Inputs	t/t feedstock	1.00	1.00
Intermediate – No Generation	MWh/t feedstock	0.42	1.69
Hydrogen Inputs	GJ/t feedstock	16.25	18.24
Intermediate Outputs	t/t feedstock	0.71	0.62
Hydrogen Outputs	GJ/t feedstock		12.89
Water Waste Outputs	t/t feedstock	0.40	0.64
Upgrading Plant			
Intermediate Inputs	t /t intermediate	1.00	1.00
Hydrogen Inputs	GJ/t intermediate	3.58	6
Electricity Inputs	MWh/t intermediate	0.14	0.21
SAF Outputs	GJ/t intermediate	15.74	17.09
RD Outputs	GJ/t intermediate	1.11	
Naphtha Outputs	GJ/t intermediate	0.78	3.74
Source		Sollai, S et al., Renewable methanol production from green hydrogen and captured CO_2: A techno-economic assessment (2023)	Hos, T, Herskowits, M. Techno-economic Analysis of Biogas Conversion to Liquid Hydrocarbon Fuels through Production of Lean-Hydrogen Syngas (2022)

PtL Inputs | Financial inputs

Table B5-2: Physical inputs and outputs by production phase for PtL by feedstock.

Variable	Sub-Variable	Units	Value	Source
Capex	Intermediate	$/t feedstock	$1,219	Bloomberg project tracker
	Upgrading	$/t intermediate	$4,204	Bloomberg project tracker
Capex Rate		% per annum	-1.0%	WEF
Capex Multiplier	Pioneer	Multiplier	1.17	US Department of Energy
	Nth Facility	Multiplier	1	US Department of Energy
Fixed Opex	Other	% capex	2%	Santos, C et al., (2018)
	Overhead	% capex	2%	RSB (2024), *Report on the Techno-Economic Assessment of SAF Pathways*
	Maintenance	% capex	2%	Santos, C et al., (2018)
	Labour Cost	% capex	3%	Santos, C et al., (2018)

Figure B5-1: PtL feedstock cost inputs[1,2]



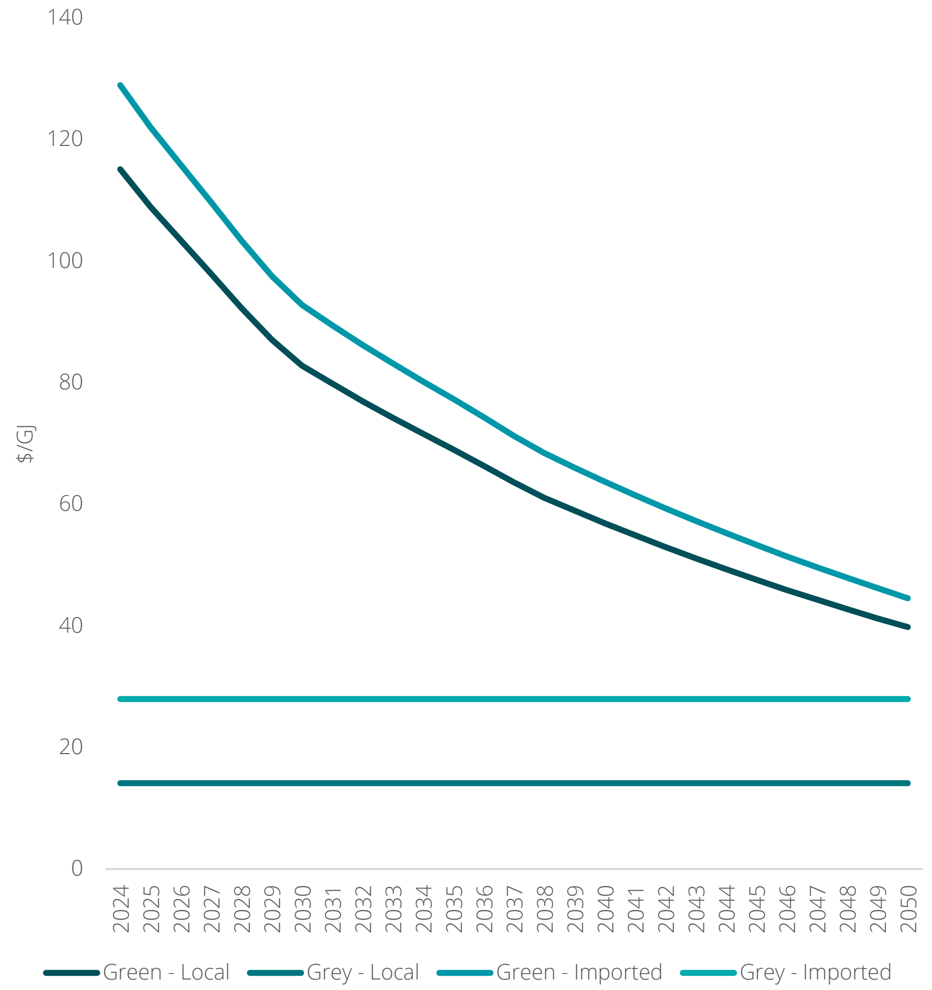
Notes: 1. Biogenic carbon dioxide is assumed as the feedstock at a fixed cost of $200/t. 2. Transport costs are developed from CSIRO TraNSIT.

PtL Inputs | Feedstock Inputs

Table B5-4: PtL Feedstock price growth rate determination and transport costs.

Feedstock	Low	Medium	High	Transport Distance (km)	Transport Cost ($/t/km)	Source
Methanol	Long-term average data	20 year average data	10 year average data	Transport costs are incorporated into the hydrogen price. Carbon Dioxide is assumed to be transported 200 km with the cost included in the feedstock price.[1]		Growth Rates: Derived from DAFF (2023). *Agricultural Commodities and Trade data - Australian economy – farm sector* Transport: CSIRO
FT	Long-term average data	20 year average data	10 year average data			

Figure B5-2: PtL feedstock price – hydrogen1



Notes: 1. Hydrogen prices are based upon Deloitte's Hydrogen and Hydrogen-Derivatives GVCE.

Appendix B6: Other Inputs and Scenario Variables

Key Scenario Variables | Cost model overview

Table B6-2: Key production cost variables

Assumption	Sub-assumption	Units	Low	High	Source
CAPEX Contingency	Intermediate Low	% of capex	10	30	Assumed ranges developed from the maximum for oil and gas from Flybberg Database accessed from "How Big Things Get Done".
	Upgrading Low	% of capex	10	30	
Renewables Type	Behind-the-meter Renewable	$/MWh	123	307	Low: Deloitte GVCE Hydrogen and Hydrogen-Derivatives Cost Model High: Based upon regional retail electricity prices from WA Government.
Escalation Rate	Capex - High	% p.a.	2	3	Assumed based upon target inflation rate.
	Revenue - High	% p.a.	2	3	
	OPEX – High	% p.a.	2	3	
Electricity Real Price Growth Rates	Behind-the-meter Renewables	% p.a.	-4.1		Assumed based upon Deloitte GVCE Hydrogen and Hydrogen-Derivatives Cost Model.

Key Scenario Variables | Cost model overview

The evolution of future Australian LCLF supply costs will turn on the scale of demand that emerges for domestic production. To provide the market with an informed assessment of potential future supply cost dynamics, this study develops two pricing scenarios: a current trajectory and an optimistic trajectory.

Within the **current trajectory scenario**, future production costs remain primarily flat, as technology innovations and process learning rates are countered by price competition to secure feedstock supplies. In this scenario, the relative competitiveness of synthetic fuel improves as ongoing renewable deployments reduce electricity and therefore hydrogen costs.

Within the **optimistic trajectory scenario,** it is assumed that the emergence of material demand drives economies of scale advantages in the form of expanded plant capacity. In response to a strong demand signal and competition between technology-feedstock pathways, technology deployments, yield improvements and higher feedstock collection rates may also push production costs down.

Table B6-2 provides an overview of the key scenario variables applied, and Figure B6-1 and B6-2 overleaf present the cost outputs for both scenarios.

Table B6-2: Key production cost variables

Variable	Notes	Sub-variable	Units	Optimistic Trajectory	Current Trajectory
Plant Capacity	The plant capacity is set in tonnes of SAF produced.	Plant Capacity	t SAF	HEFA: 400,000 Others: 80,000	All: 50,000
Feedstock Price Type & Growth Rate	P90, P50 and spot prices for feedstocks can be selected. A high, medium or low growth rate can be selected.	Feedstock Price Type	Type	P50	P90
		Feedstock Price Growth Rate	Type	Low	Medium
Supply Chain Configuration	The option for a hub-and-spoke, hub-and-hub and integrated hub supply chain can be selected.	-	Type	Hub	Hub
Physical Inputs	Yield by intermediate and upgrading, hydrogen supply type, electricity supply type and the use of process generated electricity can be flexed.	Intermediate / Upgrading Yield Type	Type	High / High	Low / Low
		Hydrogen Supply Type	Type	Green – Locally produced	Green – Locally produced
		Electricity Supply Type	Type	Imported (if process generation unviable)	Imported (if process generation unviable)
		Intermediate Electricity Generation or No Generation (Purchase)	Type	Generation	Generation
		Excess Electricity Use	Type	Use in Upgrading	Use in Upgrading
Financial Inputs	Capex contingency for the intermediate and upgrading plants, the determination of FOAK or NOAK plant type, the IRR target, discount rate, DSCR and nominal price growth rates can be flexed.	Intermediate Contingency	Type	Low	High
		Upgrading Contingency	Type	Low	High
		CAPEX FOAK/NOAK	Type	NOAK	NOAK
		IRR Target	%	10%	10%
		Discount Rate	%	10%	10%
		DSCR	Multiple	1.8	1.8
		Nominal Price Growth Rate	Type	Low	Low

Notes: 1. FOAK abbreviates First of a Kind, projects that are pioneers of a technology or design. 2. NOAK abbreviates Nth of a Kind, subsequent projects using a technology or design

Key Scenario Variables | Cost model overview

Figure B6-1: Current trajectory 2025 SAF prices

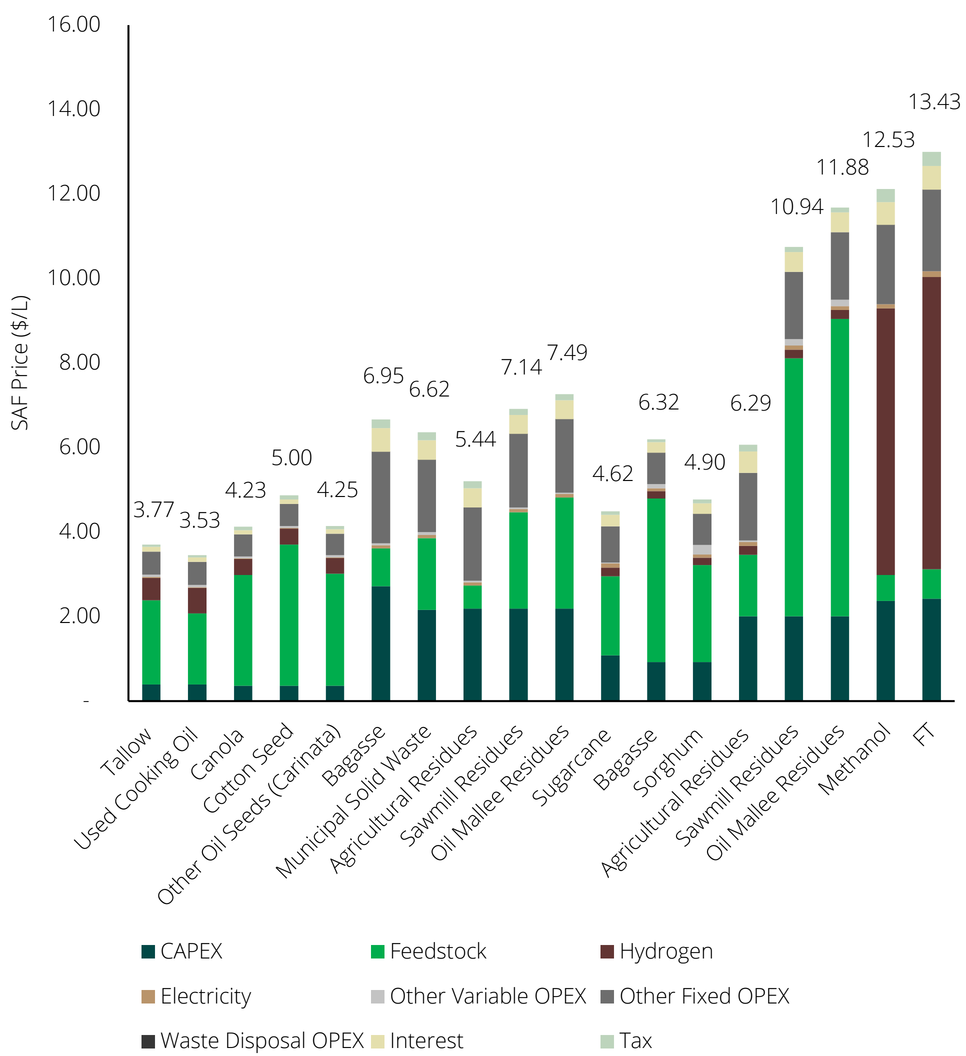
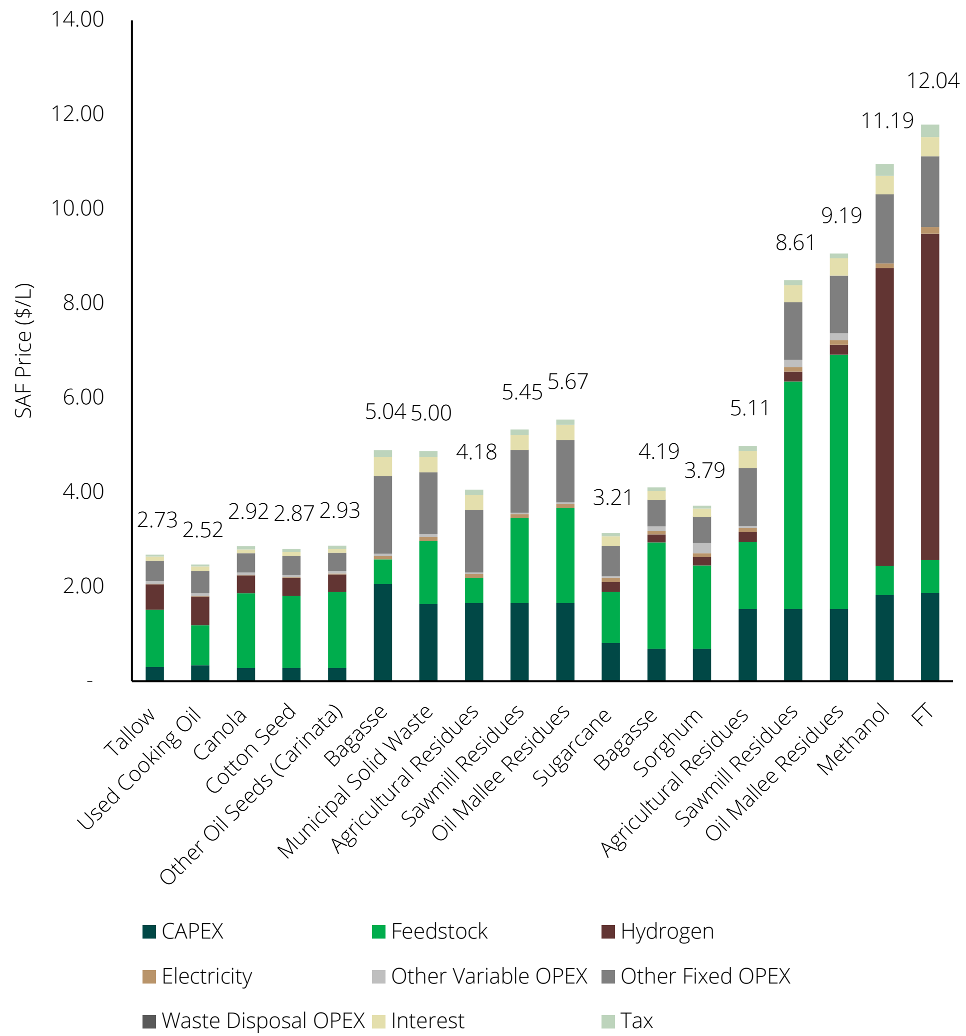


Figure B6-2: Accelerated trajectory 2025 SAF prices



Appendix B7: Feedstock Multi-Criteria Analysis

Feedstock Ladder | MCA setup

The feedstock ladder in Chapter 4 has been developed to assess the feedstock/fuel combinations to be prioritised as the industry develops.

Seven criteria have been applied to assess each feedstock/fuel production pathway within this work. Table B7-1 outlines the criteria, weightings and criteria ranks utilised to undertake this assessment.

A multi-criteria analysis (MCA) has been performed to rank each feedstock in order of priority for development. Feedstock/fuel combinations with a rank of:

- 1 are considered viable today.
- 3 are considered near term viable.
- 8–9 are considered long term viable.
- 10+ require a technological breakthrough to become long term viable.

Table B7-1: Feedstock ladder assessment criteria, weightings and criteria ranks

Criteria	Weighting	Value	Low	Medium	High
Cost of Production	16%	Feedstock/fuel combinations with a lower cost of production are going to be more favourable to offtakers.	Cost of production below AU$4.00	Cost of production below or equal to AU$6.00/L	Cost of production above AU$6.00/L
Abatement Cost	16%	Feedstock/fuel combinations with a lower abatement cost offer a higher potential for adoption whilst requiring less government support to get to market.	Abatement cost below AU$1,200/t$CO_2$-e	Abatement cost below or equal to AU$2,000/t$CO_2$-e	Abatement cost above AU$2,000/t$CO_2$-e
Ease of Aggregation	16%	Feedstocks which are easier to sort and aggregate offer better potential for fuel production.	Feedstock is not aggregated	Feedstock is aggregated but faces pre-treatment challenges	Feedstock is already aggregated
Feedstock Supply Potential	16%	Feedstocks with a greater supply potential, either with existing availability or the capacity to increase supply (e.g. through crop rotations of enhanced collection) offer greater potential for fuel production.	Feedstock supply results in less than one BL of fuel and there is limited pathways to boost supply	Feedstock supply can exceed one BL of fuel and/or can be boosted (e.g. through crop rotations)	Unlimited feedstock supply
Feedstock price Dynamics	10%	Feedstocks which are likely to face declining competition from alternative uses (and hence can experience real cost declines over time) offer a better pathway for lowering end fuel and abatement cost.	Competing demand/constrained supply is likely to see real price increases	Competing demand WTP or the scale of competing demand could decline seeing real price falls	Feedstock price is anticipated to decline substantially in real terms
Yield Improvement Potential	10%	Feedstock/fuel pathways which have the potential for substantial yield improvements over time offer a better pathway for lowering end fuel and abatement cost.	The yield from the process is already optimised	The process yield can be improved moderately through process optimisation (e.g. external hydrogen feed or sugar extraction).	A step change in yield is likely
Fuel Price Dynamics	16%	Fuels which remain resiliently more competitive then PtL based production within this work offer a better pathway to market.	The fuel is lower cost than the cheapest PtL pathway through to 2050.	The fuel is the cheapest PtL pathway.	The fuel is a higher cost than the cheapest PtL pathway through to 2050.

Feedstock Ladder | MCA setup

Table B7-1: Feedstock ladder assessment criteria, weightings and criteria ranks

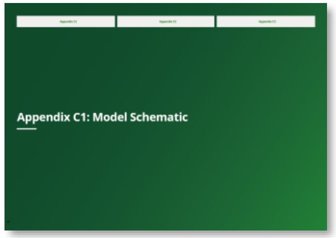
Variable	Tallow	Used Cooking Oil	Canola	Cotton Seed	Other Oil Seeds (Carinata)	Bagasse	Municipal Solid Waste	Agricultural Residues	Sawmill Residues	Oil Mallee Residues	Sugarcane	Bagasse	Sorghum	Agricultural Residues	Sawmill Residues	Oil Mallee Residues	Methanol	FT
Production Pathway	HEFA	HEFA	HEFA	HEFA	HEFA	FT	FT	FT	FT	FT	AtJ	AtJ	AtJ	AtJ	AtJ	AtJ	PtL	PtL
Cost of Production	High	High	Medium	Medium	Medium	Medium	Medium	Medium	Low	Low	Medium	Low	Low	Low	Low	Low	Low	Low
Abatement Cost	High	High	Medium	Low	High	Medium	Medium	High	Medium	Medium	Medium	Medium	Medium	Medium	Low	Low	Low	Low
Ease of Aggregation	High	High	High	High	High	High	Medium	Low	Low	Low	High	High	High	Low	Low	Low	Medium	Medium
Feedstock Supply Potential	Low	Low	Medium	Low	Low	Low	Medium	Medium	Low	Low	Low	Low	Low	Medium	Low	Low	High	High
Feedstock price Dynamics	Low	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Low	Medium	Low	Medium	Medium	Medium	High	High
Yield Improvement Potential	Low	Low	Low	Low	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Fuel Price Dynamics	High	High	High	High	High	High	High	High	Low	Low	High	Low	Low	Low	Low	Low	Medium	Low
Rank	1	1	4	8	3	6	10	7	14	16	5	12	11	15	16	16	9	13

Appendix C: Market Clearing

Appendix C | Market Clearing Appendix Overview

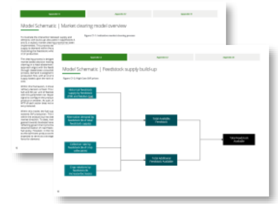
Appendix C summarises the schematics, inputs, assumptions, specifications and outputs of the LCLF Market Clearing Model.

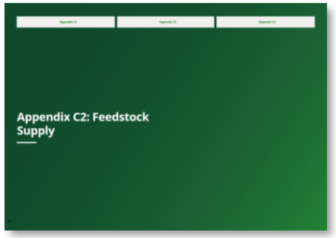
This includes an indicative view of the market clearing process in how supply is matched to the demand built in previous appendices. High and low values for supply and collection rates of relevant feedstocks are presented followed by ACCU, SAF, RD and Hydrogen supply and demand outputs of the cleared model.



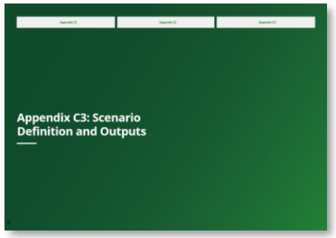
Includes an indicative market clearing process where the build-ups in Appendices A and B are matched.

Includes a schematic on the build-up to total feedstock available.

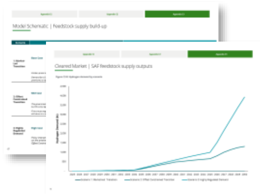




Sets out high and low values for supply and collection rates for each of the 12 biogenic feedstocks examined in the study with associated supply growth rates.



Defines the demand and supply dynamics specified under each of the three market scenarios studied. From this, ACCU demand, SAF and RD supply outputs are presented along with hydrogen demand for each scenario.



Appendix C1: Model Schematic

Model Schematic | Market clearing model overview

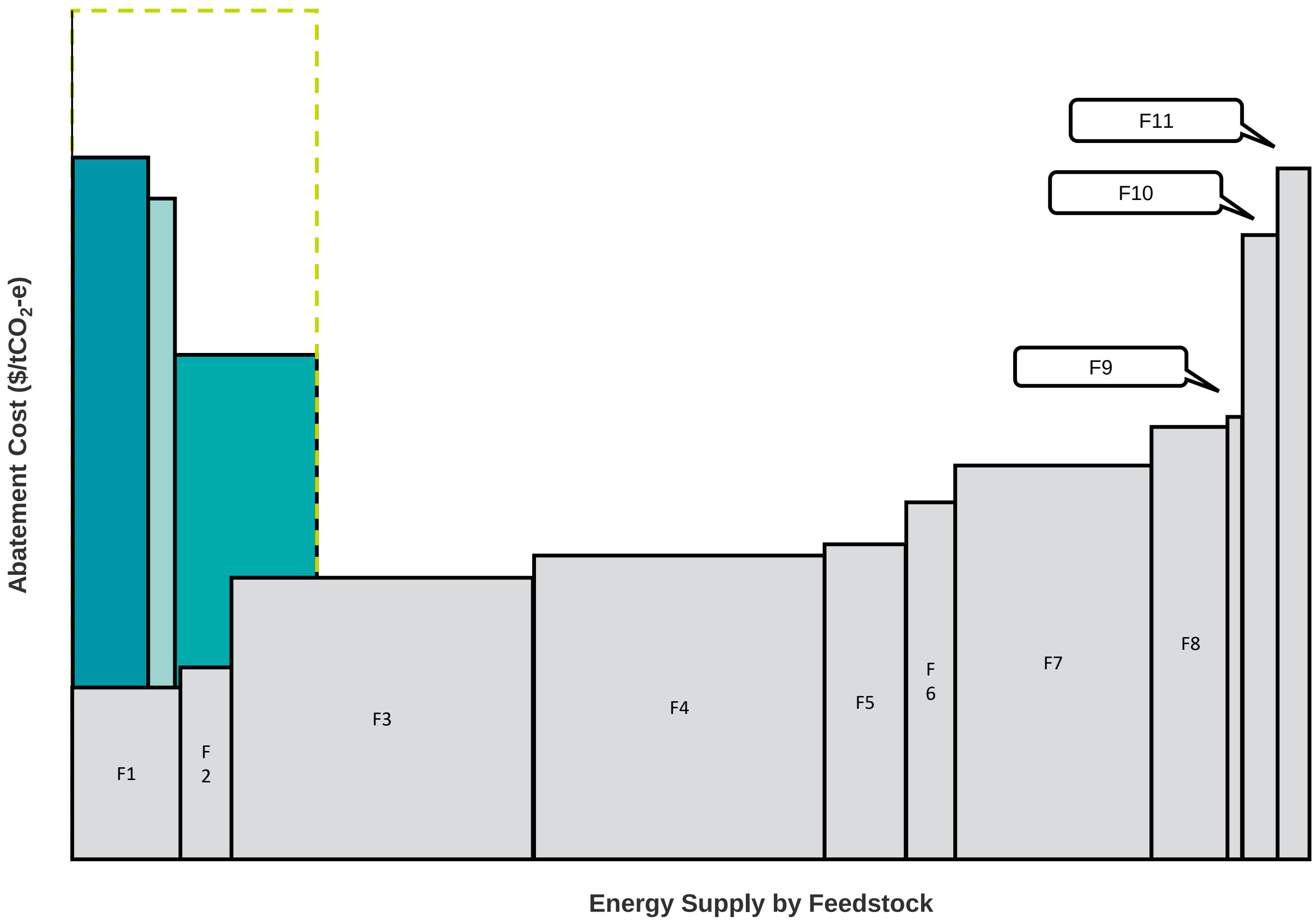
To illustrate the interaction between supply and demand, with build-ups discussed in Appendices A and B, a stylistic market clearing process has been implemented. This process assigns feedstock supply to demand within the aggregate market, illustrating the feedstocks which are utilised for LCLF production.

The clearing process is designed to illustrate market-based decision making, with demand clearing on a least-abatement cost basis. This approach aligns with the feedback provided through stakeholder consultations. Through this process, demand is assigned to the lowest cost of production first, with all LCLF demand matched to supply based upon the rank ordered abatement cost.

Within this framework, it should be noted that the refinery decision is fixed. This means the volume of SAF and RD per unit of feedstock input is fixed, with this parameter not responding to a market signal to configure the product slate toward one product or another. As such, the differentiated WTP of each sector does not vary what products are produced.

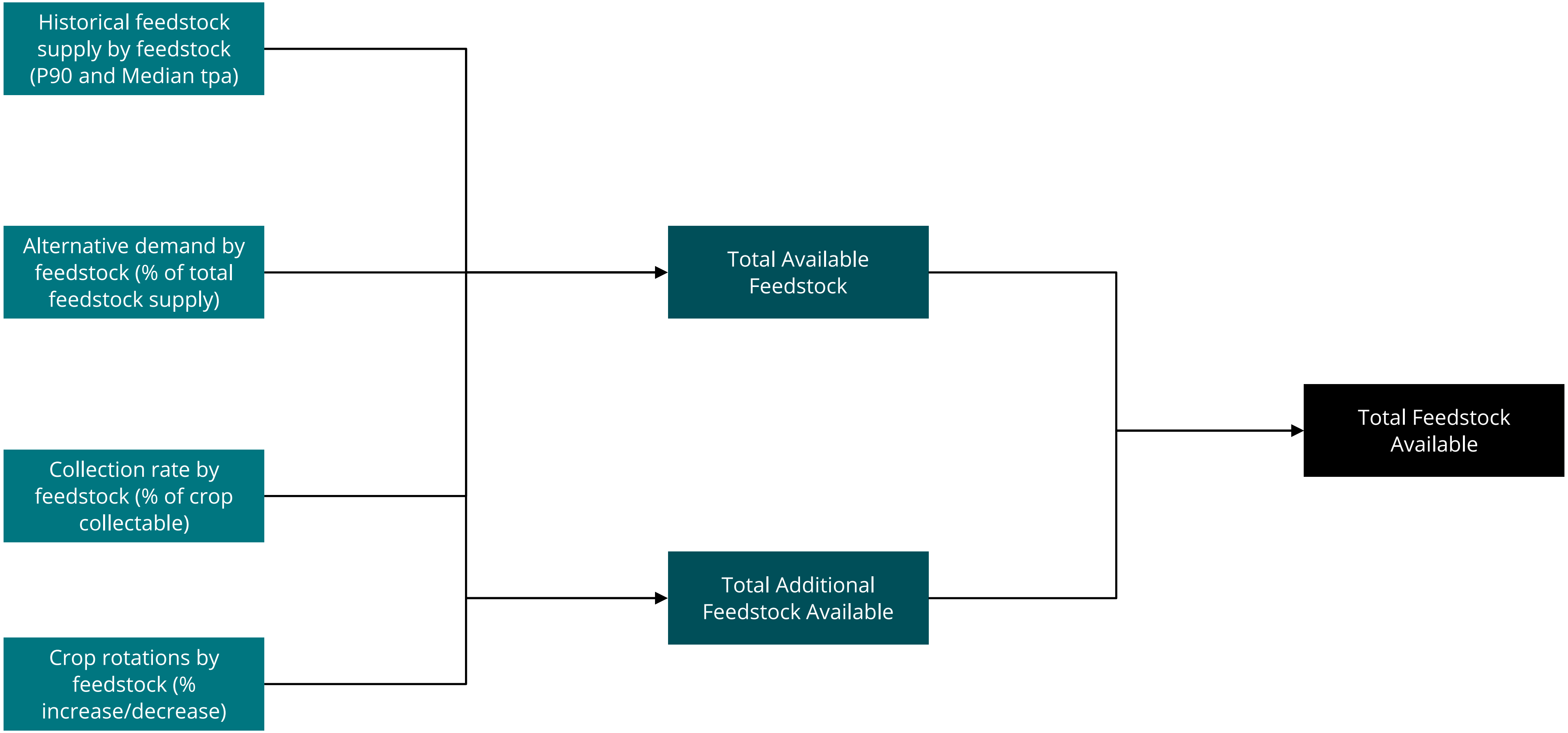
Within this model, the fuel supply is tailored towards SAF production. This is noted to be a limit within the analysis but has been determined due to market direction. To date, markets have been geared towards biodiesel/renewable diesel supply reflecting government prioritisation of decarbonisation of road fleets or fuel security in fuel policy. However, in the model SAF is produced as the dominant product as the aviation sector is expected to serve as a stronger long-term driving force for demand.

Figure C1-1: Indicative market clearing process



Model Schematic | Feedstock supply build-up

Figure C1-2: High Case SAF prices



Appendix C2: Feedstock Supply

Model Schematic | Feedstock supply build-up

Figure C2-1: Feedstock supply inputs

Feedstock	Supply (P90) (Mt)	Supply (Median) (Mt)	Low Collection Rate (%)	High Collection Rate (%)	Feedstock Growth Rate (%)	Sources
Sugarcane	37.86	30.19	100	100	0.85%	Supply and Intensity: DAFF "Agricultural Commodities and Trade Data" (2023). Approximated using "Rural commodities – sugar XLSX" Growth rate: Used 20-year yield CAGR from supply data.
Bagasse	8.34	9.72	100	100	1.37%	Supply and Intensity: DAFF "Agricultural Commodities and Trade Data" (2023). Approximated using "Rural commodities – sugar XLSX" Growth rate: Used 20-year yield CAGR from supply data.
Sorghum	0.91	1.93	100	100	0.57%	Supply and Intensity: DAFF "Agricultural Commodities and Trade Data" (2023). Approximated using "Rural commodities – course grains XLSX" Growth rate: Used 20-year yield CAGR from supply data.
Tallow	0.32	0.50	100	100	0.50%	Supply: FAO Data "Crops and livestock products" (2023) Growth rate: Assumed in line with low growth rate used in CSIRO SAF Roadmap
Used Cooking Oil	0.10	0.10	100	100	0.50%	Supply: DCCEEW National Waste Report 2022. Approximated using "National Waste Database 2022 XLSX" Growth rate: Assumed in line with low growth rate used In CSIRO SAF Roadmap
Municipal Solid Waste	12.63	13.47	30	40	0.50%	Supply: Volumes assumed in CSIRO SAF Roadmap . Growth rate: Assumed in line with low growth rate used in CSIRO SAF Roadmap .
Agricultural Residues	18.59	27.70	30	50	1.32%	Supply and Intensity: DAFF "Agricultural Commodities and Trade Data" (2023). Approximated using "Rural commodities – forestry XLSX" Growth rate: Used 20-year yield CAGR from supply data. Assumed Ag Residues change reflects the weighted average changes in barley, wheat, oats and sorghum.
Sawmill Residues	5.24	6.03	30	50	0.72%	Supply and Intensity: DAFF "Agricultural Commodities and Trade Data" (2023). Approximated using "Rural commodities – forestry XLSX" Growth rate: Used 10-year yield CAGR from supply data.
Oil Mallee Residues	0.19	0.19	30	50	0.50%	Supply: Australian Biomass for Bioenergy Assessment Growth rate: Assumed in line with low growth rate used in CSIRO SAF Roadmap
Canola	0.75	2.36	100	100	2.03%	Supply and Intensity: DAFF "Agricultural Commodities and Trade Data" (2023). Approximated using "Rural commodities – oilseeds XLSX" Growth rate: Used 20-year yield CAGR from supply data.
Cotton Seed	0.29	0.72	100	100	0.40%	Supply and Intensity: DAFF "Agricultural Commodities and Trade Data" (2023). Approximated using "Rural commodities – cotton XLSX" Growth rate: Used 20-year yield CAGR from supply data.
Other Oilseeds	0.04	0.08	100	100	1.96%	Supply and Intensity: DAFF "Agricultural Commodities and Trade Data" (2023). Approximated using "Rural commodities – oilseeds XLSX" Growth rate: Used 20-year yield CAGR from supply data.

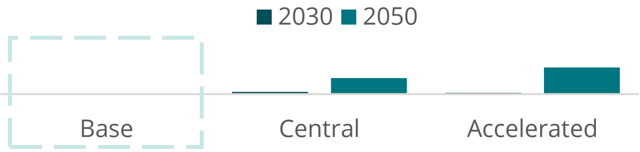
Appendix C3: Scenario Definition and Outputs

Model Schematic | Feedstock supply build-up

Scenario	LCLF Demand Dynamics	LCLF Supply Dynamics

1: Market-Led Transition

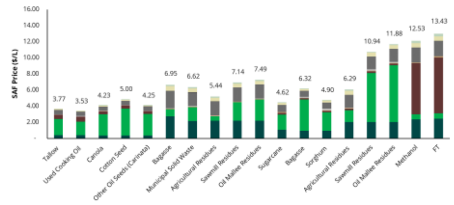
Base Case



Carbon prices remain too low to drive significant LCLF uptake across most sectors.

Demand for LCLF is driven by a small subset of end customers willing to pay significant premiums to reduce their scope 3 emissions.

Current Trajectory

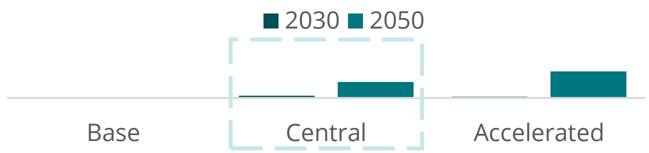


Production costs remain largely flat, as technology innovations are countered by price competition to secure feedstock supplies.

Synthetic fuels become more competitive as ongoing renewable deployments reduce electricity and therefore hydrogen costs.

2: Offset Constrained Transition

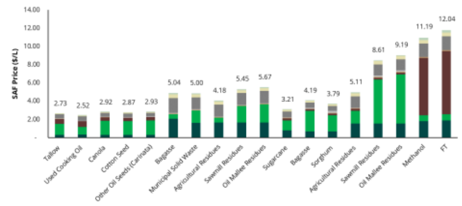
Central Case



The government intervenes to cap use of ACCUs to meet decarbonisation obligations at 30%, but this only applies to Safeguard Facilities.

Firms must engage in on site decarbonisation initiatives to meet their remaining obligations but still do so in a rational manner – prioritising lower abatement cost initiatives over higher ones.

Optimistic Trajectory



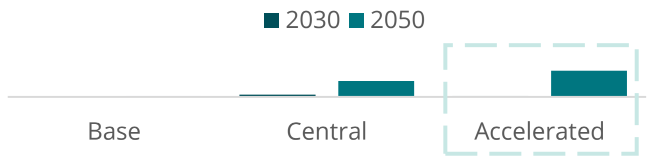
The emergence of material demand triggers a positive supply side response, driving significant technology deployment and competition between pathways and feedstocks.

Relative to a market-led transition, production costs fall faster driven by economies of scale and process innovation. Cost improvements are gradually realised in the market.

Feedstock collection rates rise in response to proven fuel demand, increasing availability of biogenic feedstocks.

3: Highly Regulated Demand

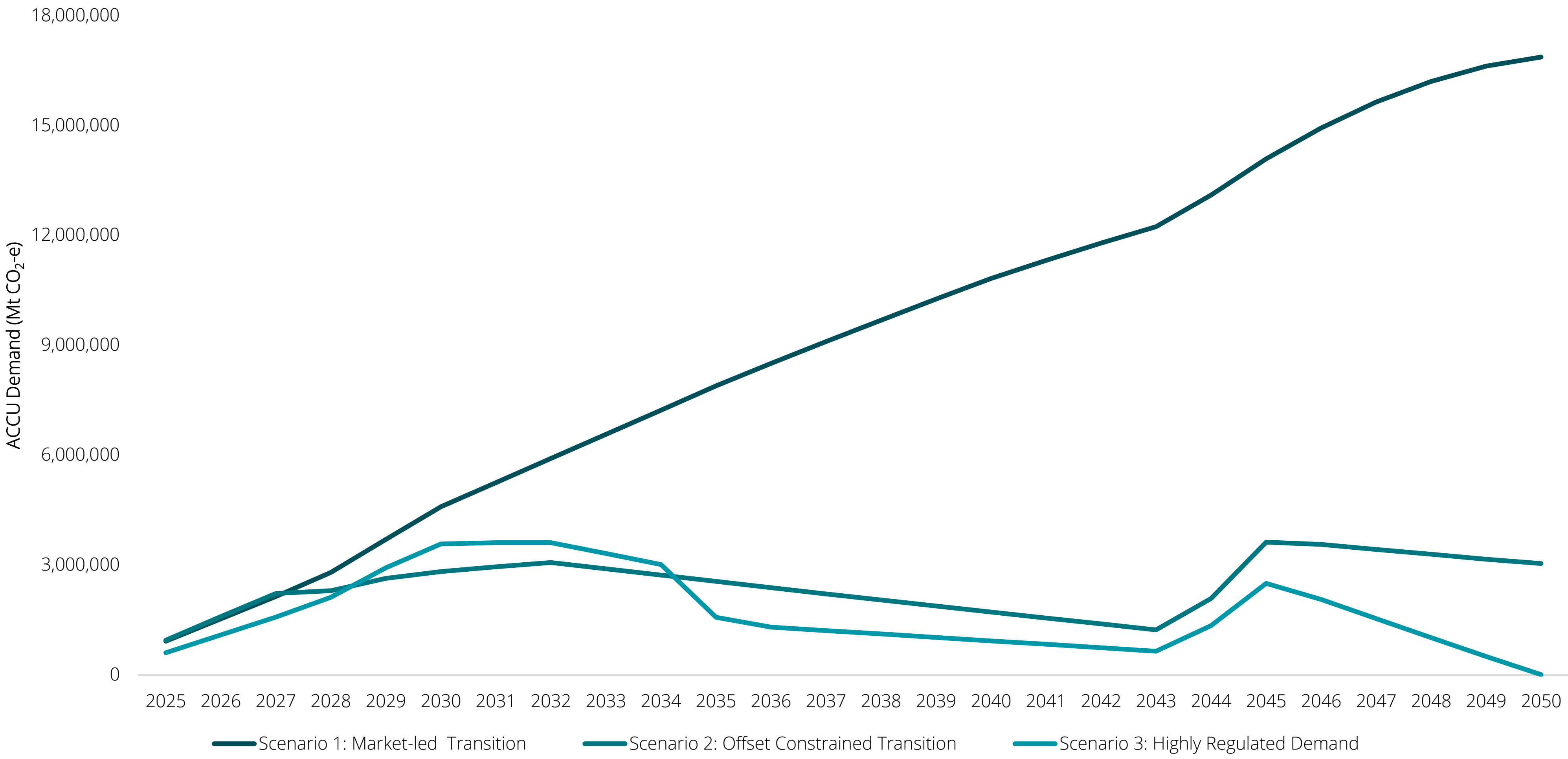
Accelerated Case



Policy intervention mandates LCLF uptake in a manner identical to the ReFuelEU policy on the aviation and maritime sectors. Demand for other sectors as consistent with the Offset Constrained Transition Scenario.

Cleared Market | ACCU demand by scenario

Figure C3-1: ACCU demand by scenario



Cleared Market | SAF feedstock supply outputs

Figure C3-2: Market-led Transition feedstock supply

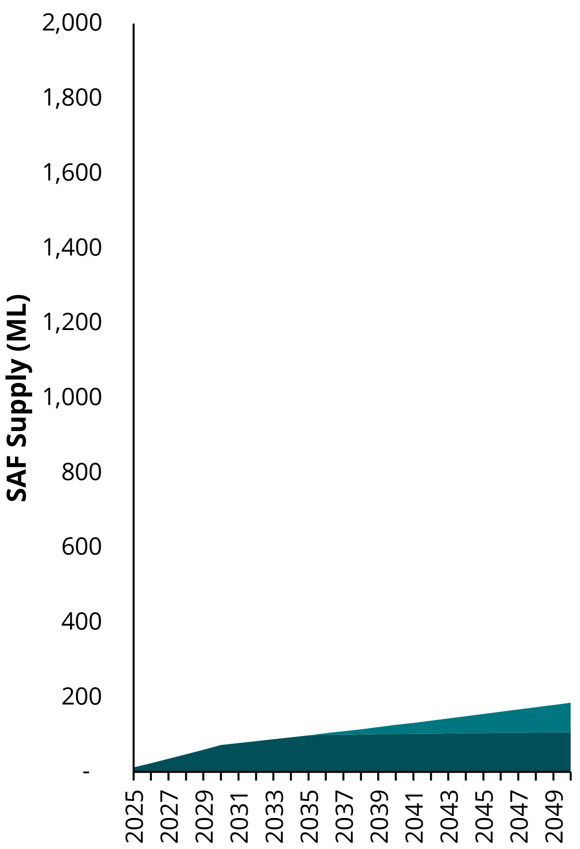


Figure C3-3: Offset Constrained Transition feedstock supply

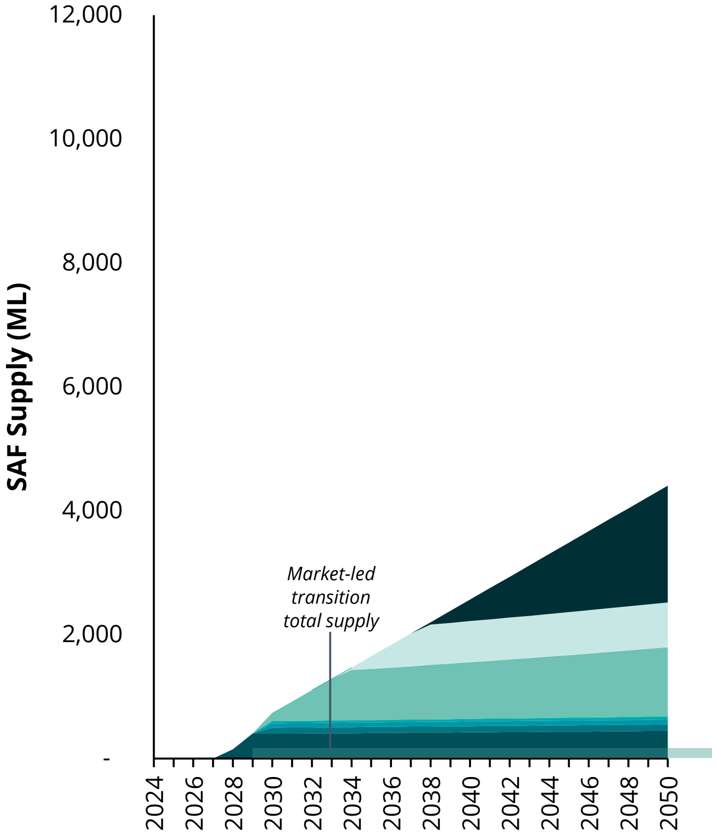
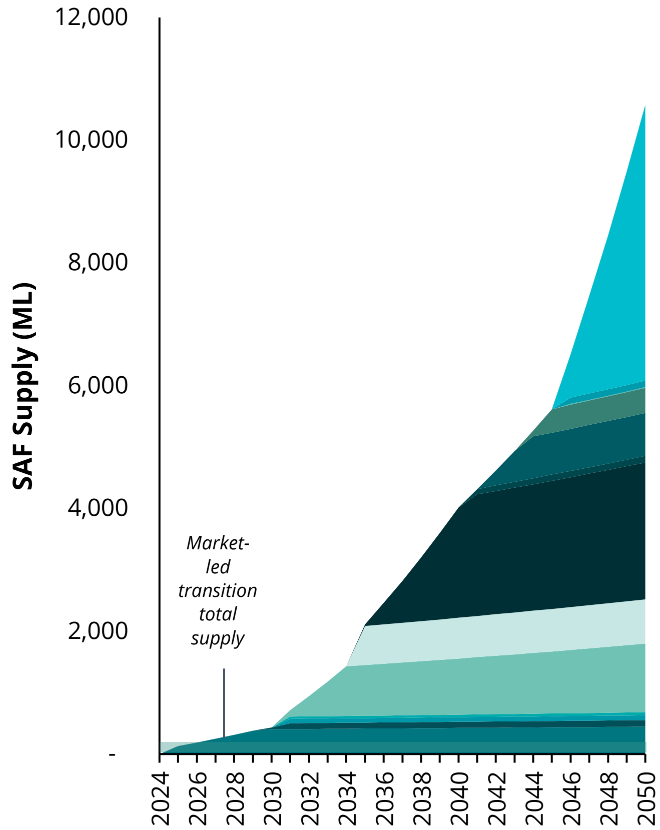


Figure C3-4: Highly Regulated Demand feedstock supply



Tallow | Used Cooking Oil | Cotton Seed | Other Oilseeds | Canola
Sugarcane | Agricultural Residues | Bagasse | Municipal Solid Waste | Bagasse
Sawmill Residues | Oil Mallee Residues | Sorghum | PtL Methanol | PtL FT
Agricultural Residues | Oil Mallee Residues | Sawmill Residues

Cleared Market | RD feedstock supply outputs

Figure C3-5: Market-led Transition feedstock supply

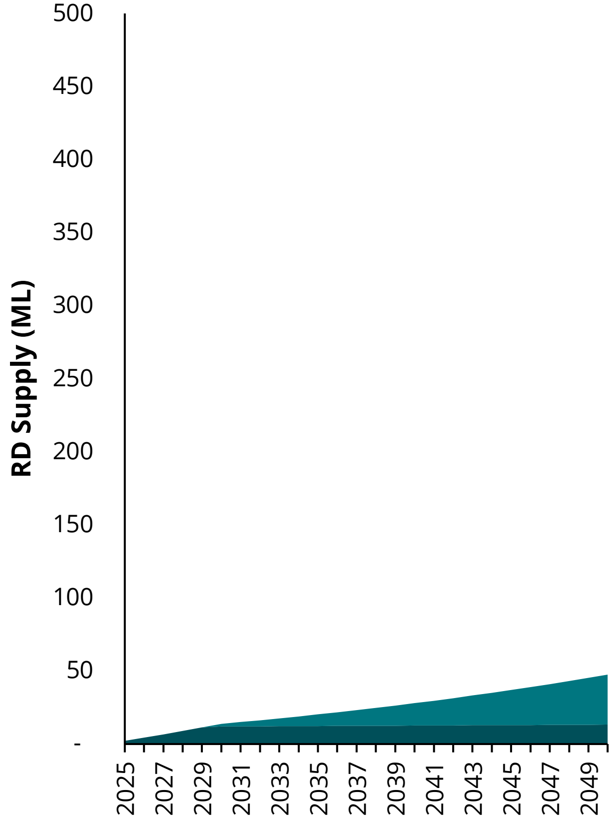


Figure C3-6: Offset Constrained Transition feedstock supply

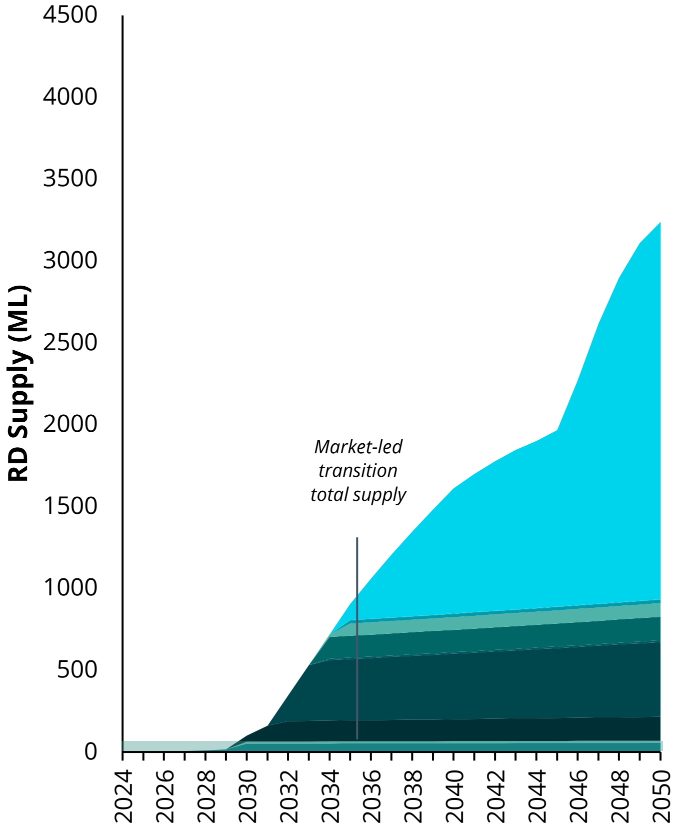
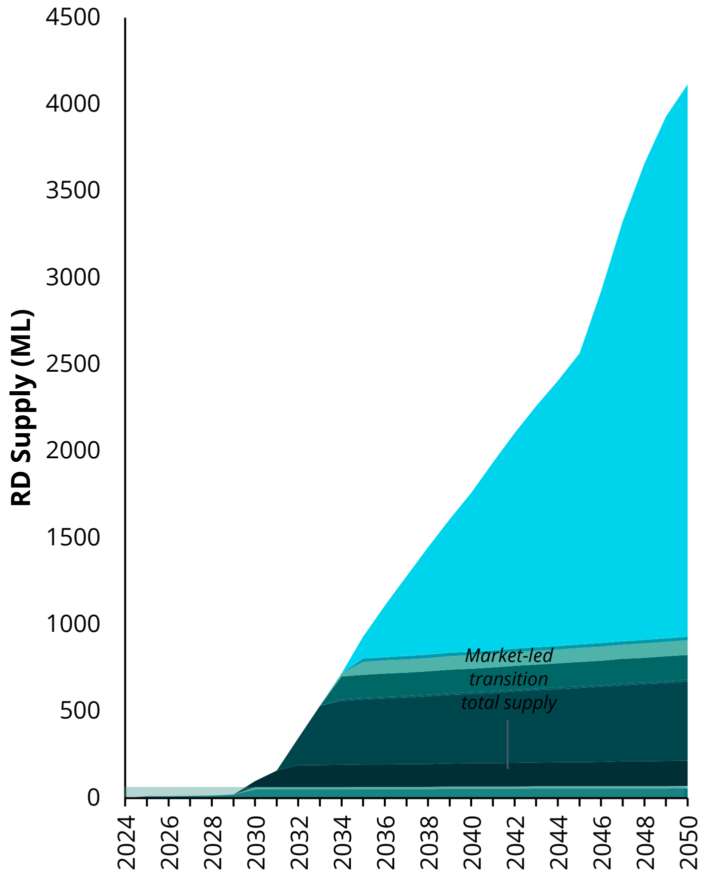


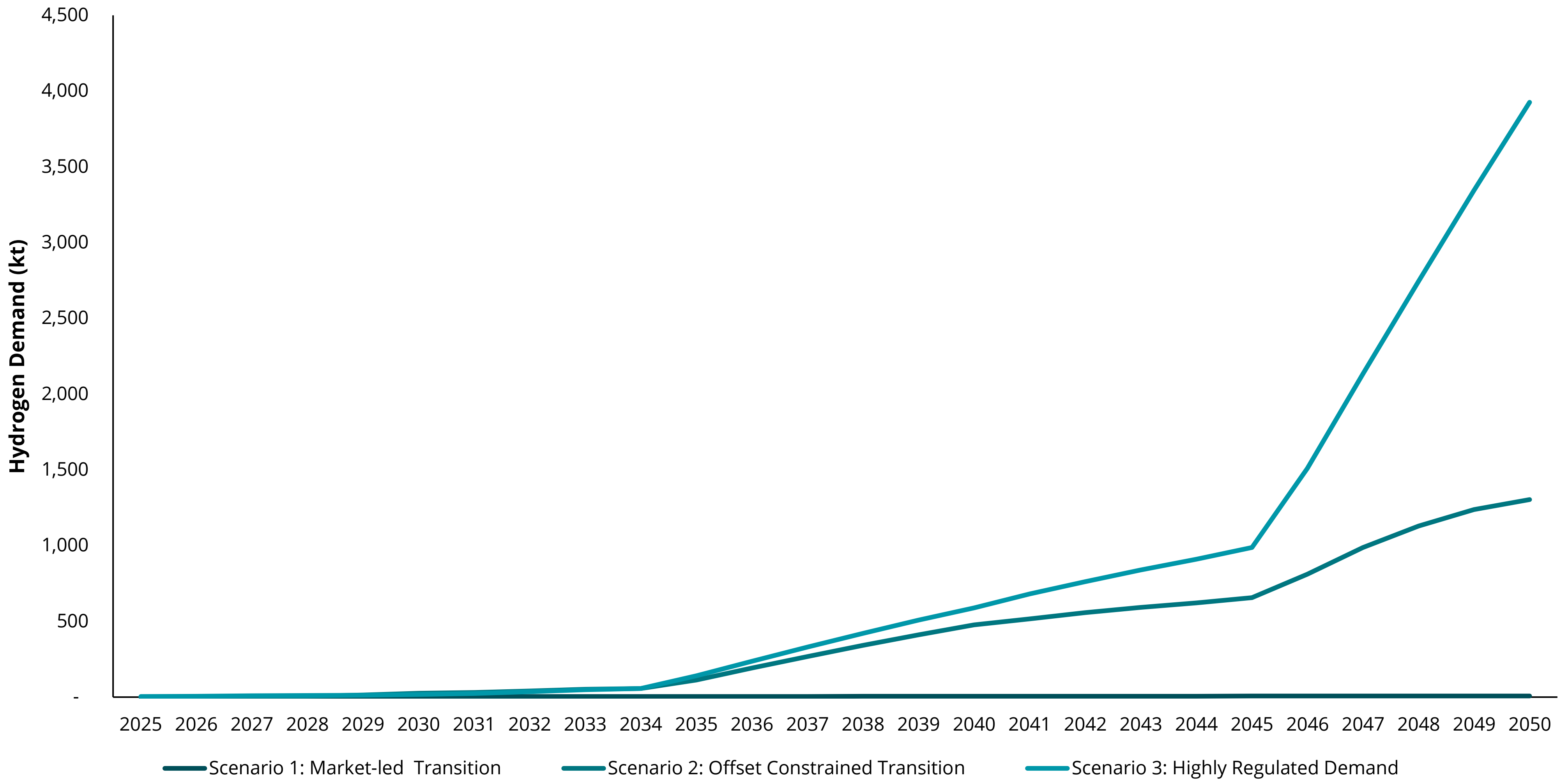
Figure C3-7: Highly Regulated Demand feedstock supply



Used Cooking Oil | Tallow | Cotton Seed | Canola | Used Cooking Oil | Other Oilseeds | Sugarcane
Agricultural Residues | Bagasse | Municipal Solid Waste | Bagasse | Sawmill Residues | Sorghum | Oil Mallee Residues
PtL Methanol | Agricultural Residues | PtL FT | Oil Mallee Residues | Sawmill Residues

Cleared Market | Hydrogen demandy outputs

Figure C3-8: Hydrogen demand by scenario



Appendix D: Action Options

Options long list to address investment risks mapped by market participant

Figure C3-8: Investment risks

	Feedstock & Fuel Producers	Fuel Users	Investors	Policymakers
Barrier 1: Uncertain Demand	• Develop strategic partnerships with major end users to support their decarbonisation • Engage directly with international offtakers • Prioritise product flexibility to diversify revenue streams	• Publish forward expectations of uncontracted LCLF demand • Run pooled offtake tenders with clear volume, carbon intensity, and price thresholds • Normalise 10-year offtake agreements • Commodify scope 3 emissions savings for end customers	• Leverage client networks to pool demand across markets • Publish consensus ACCU price forecasts & implications for LCLF uptake • Support both balance sheet-led and project-finance led commercial models • Leverage concessional finance to reduce financing costs	• Explore viable demand-side measures • Level the playing field for LCLF with regards to the fuel tax credit • Undertake regional trade policy to increase APAC fuel demand and secure access to prospective export markets
Barrier 2: Price Risk	• Clarify preferred pricing structures (e.g. cost plus, cap and collars)	• Support standardised price indexing for contracts • Make direct or indirect investments in LCLFs projects	• Reach consensus on a price discovery mechanism • Drive standardisation of key contract terms (premium/discount for carbon intensity, risk allocation) • Support dissemination of price benchmarks (e.g. feedstock prices)	• Explore potential revenue certainty mechanisms such as a contract for difference or margin-linked incentives
Barrier 3: Feedstock Risk	• Advance projects for feedstock aggregation and processing • Develop longer term feedstock offtake contracts with revenue sharing provisions • Develop sophisticated feedstock sourcing platforms to manage volatility • Undertake R&D to deliver carbon intensity reductions, crop yield improvements, and fuel yield improvements	• Invest in diversified feedstock supply chains • Develop partnerships with multiple feedstock suppliers	• Assess viability & demand for development of a feedstock insurance market • Incentivise long term feedstock supply agreements • Mandate traceability and supply chain transparency for feedstock suppliers	• Develop a national feedstock strategy including accounting for competing land uses • Develop a national feedstocks data asset with regular feedstock seasonal outlooks • Consider capital support for feedstock collection, aggregation and processing infrastructure
Barrier 4: Technology Risk	• Actively gather and share operational and commercial learnings from international markets	• Support competition between production technologies, including by trialling fuel supplied by new entrants and engaging with OEMs	• Explore use of public performance guarantees or credit enhancements • Facilitate market access for technology performance insurance suppliers • Support development of the EPC market	• Provide grant funding to advance new technologies and business models such as hub-spoke facilities • Facilitate trade delegations to increase connections between domestic market players and global innovators
Barrier 5: Policy Risk	• Provide policymakers with transparent information regarding production cost and cost gaps • Fund independent lifecycle carbon assessments of Australian feedstocks • Assess potential land use conflicts to provide policymakers with clarity on potential industry impacts • Estimate economic benefits of industry development	• Provide policymakers with transparent information on LCLF abatement costs relative to alternatives • Provide policymakers with regular updates on international market developments, including pricing and international offtakes • Commission detailed technical studies to support interoperability of GO scheme	• Provide policymakers with detailed market intelligence on investment risks by technology and feedstock, the state of domestic pipeline, and trends in international commodity markets.	• Ensure consistency between climate and transport policy. • Review liquid fuels legislation to clarify expected quality, stockholding and other obligations for LCLF • Engage with international regulatory regimes to ensure alignment & clarify Australia's default carbon values • Prioritise the extension of GO scheme extension to LCLF, including interoperability with domestic and international book and claim schemes

Appendix E: LCLF Production Pathways

Options long list to address investment risks mapped by market participant

Figure E-1: The HEFA production pathway converts fats, oils and greases to end LCLFs through refinery processes.

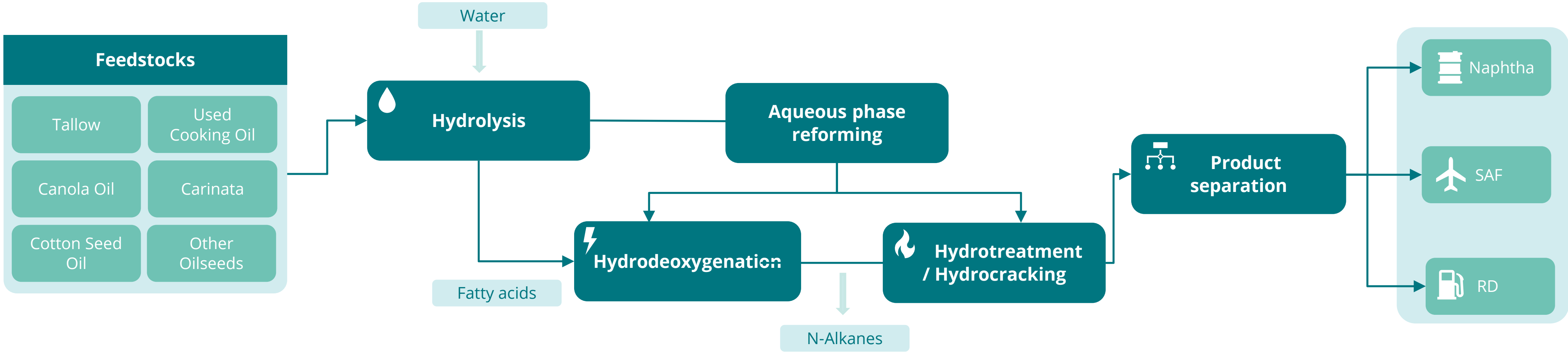
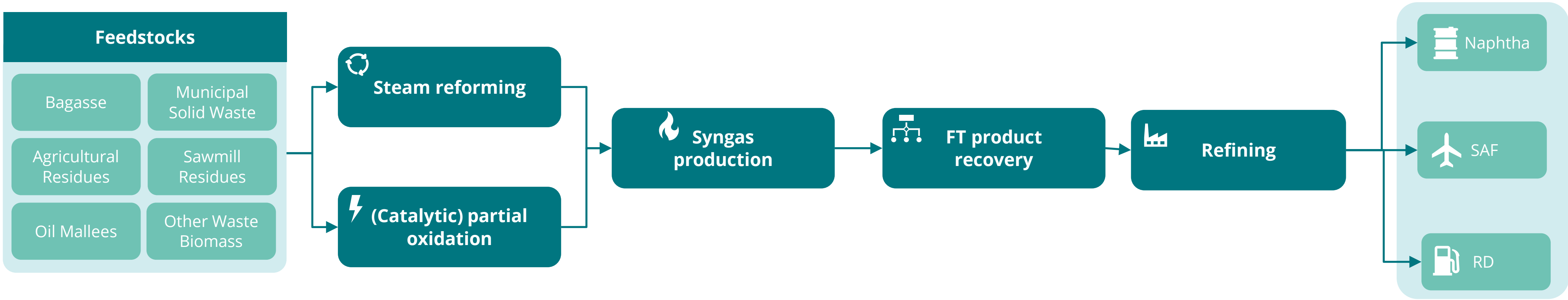


Figure E-2: The FT production pathway converts woody biomass to synthesis gas (carbon monoxide and hydrogen). This is converted to an intermediate bio-oil which is subsequently refined to LCLF products.



Options long list to address investment risks mapped by market participant

Figure E-3: The AtJ production pathway converts sugars to ethanol or propanol through fermentation. The alcohol is subsequently upgraded through refinery processes to LCLFs.

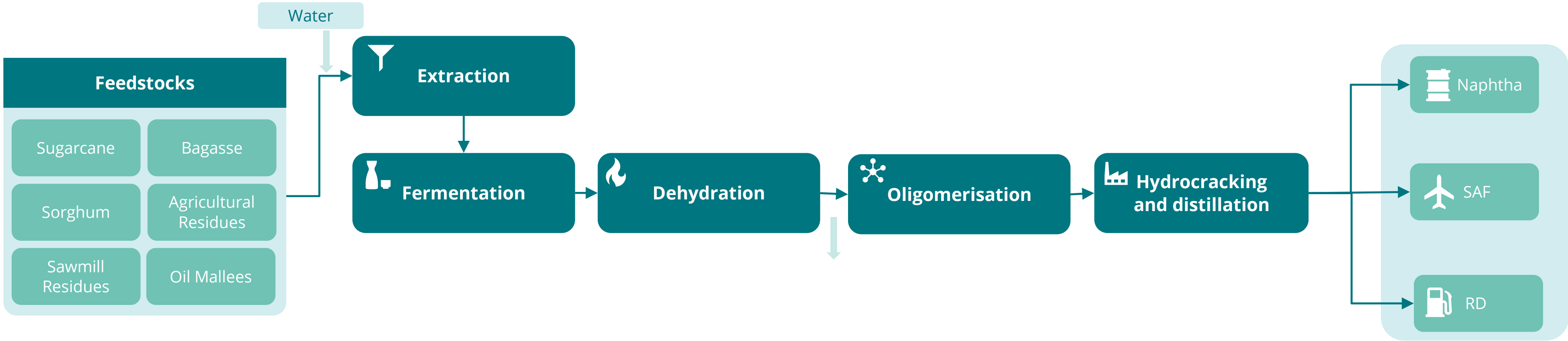
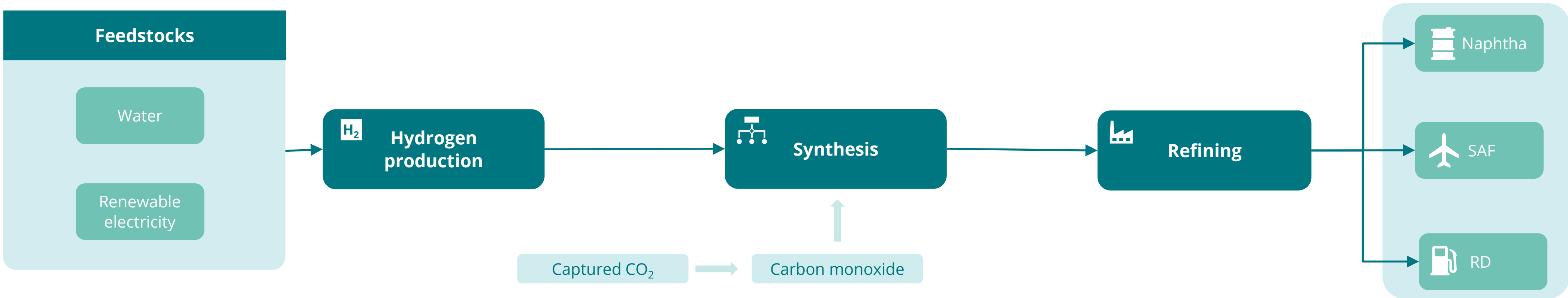


Figure E-4: The PtL production pathway converts carbon dioxide and hydrogen (synthesis gas) into either bio-oil or methanol. Refinery processes subsequently convert these intermediates into LCLFs.



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