



## Australian Sustainable Aviation Fuel Price Heuristics

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### Introduction

Boeing Australia engaged Washington State University to develop a set of Australia-centric sustainable aviation fuel (SAF) price heuristics, aka a “Rules of Thumb”, similar to those created for the International Civil Aviation Organization (ICAO). The ICAO SAF “Rules of Thumb” provide generalized estimates of SAF minimum selling price (MSP), capital investment requirements and carbon abatement costs.

The Australia-specific heuristics were created using a suite of open-source, harmonized techno-economic analyses (TEAs), adapted with cost data and financial assumptions relevant to Australia.

These scoping-level TEAs have a predicted methodological accuracy of +/- 30% and are suited for high-level comparisons. The models rely on open-source information and do not incorporate proprietary data or represent any specific commercial producer. As a result, the values presented may differ from those of individual production entities.

### Method

The primary output of this work is an Excel spreadsheet, and this document supports the data compiled in that file. All values are reported in Australian dollars (AUD) with a 2021 cost year, derived from adaptations of publicly available TEAs [1–4] following methodologies outlined in [5–8]. Both mature ( $n^{\text{th}}$ ) and pioneer facility costs and the resulting MSPs are presented as appropriate. It should be noted that hydroprocessed esters and fatty acids (HEFA) is currently the only mature conversion technology.

The Australian SAF price heuristics represent scoping-level information that enables high-level comparisons of SAF production pathways, defined as the combination of conversion technology and feedstock. The conversion technologies included in this work are HEFA, Fischer-Tropsch (FT), alcohol to jet (ATJ), and pyrolysis. All of these technologies, except for pyrolysis, are ASTM approved for SAF production [9]. Pyrolysis ASTM certification is in progress.

Australia-specific prices for feedstock, electricity, natural gas, and water were utilized in this analysis. In addition, the prices of sorted recyclables from municipal solid waste (MSW) were changed to reflect the Australian market. Feedstock availability assessments are beyond the scope of this analysis.

Additionally, key financial and operating assumptions were also matched to Australia’s value including a corporate tax rate of 30%, a labor burden of 20%, an inflation rate of 2.9%, and 20-year straight-line depreciation. Facility scales were provided by Boeing Australia: 300 million L/yr for mature,  $n^{\text{th}}$  plants and 50 million L/yr for pioneer facilities.

The FT, CO<sub>2</sub> and H<sub>2</sub> pathway is commonly referred to as power-to-liquids (PtL) or e-fuels. The TEA utilized assumes that the conversion facility purchases both hydrogen and carbon dioxide, rather than producing H<sub>2</sub> or collecting CO<sub>2</sub>. As a result, the capital costs associated with CO<sub>2</sub> collection of H<sub>2</sub> production are not included in the estimated total capital investment (TCI). Further, this facility is modeled only as an  $n^{\text{th}}$  plant because the most significant differences between  $n^{\text{th}}$  and pioneer facilities for this pathway are expected to be in the collection and manufacture of the feedstocks.

Biomass and MSW used as feedstock for FT or pyrolysis pathways require pre-processing before entering a biorefinery. These pre-processing costs were estimated using an additional harmonized TEA to quantify the cost of sorting, screening, drying, and size reduction [10].

No publicly available Australian price data for cellulosic ethanol was identified. The values used in this analysis follow the assumption that cellulosic ethanol costs are approximately twice those of ethanol produced using first generation feedstocks such as corn or sugarcane [11,12].

Brassica carinata oil, a second-crop oilseed oil, does not currently have commercial scale production, resulting in no price information. However, second-crop oilseeds are an important potential crop in Australia. As a result, it was assumed that the price of rapeseed oil could be used as a surrogate for Brassica carinata oil. For this assumption to hold, large-scale planting would be required. Further the cost of harvest (methods, equipment purchase/modifications) and the oilseed crushing are assumed to follow a similar cost structure. No sensitivity analysis was performed on this specific oilseed oil. However, it is delineated in the abatement cost calculations.

Abatement costs for SAF are defined in Equation 1 as the difference in price divided by the difference in carbon intensity (CI). This metric estimates the relative cost of avoiding 1 t CO<sub>2e</sub> in emissions. When available, CI values are the CORSIA default life cycle emission values.

$$Abatement\ Cost\ \left(\frac{\$}{tCO_2e}\right) = \frac{SAF\ MSP - petroleum\ jet\ price}{SAF\ CI - petroleum\ CI} \quad \text{Equation 1}$$

## Results

Table 1 lists the feedstocks for each conversion technology and their respective total fuel yield, feedstock prices, and the volume of SAF for both n<sup>th</sup> and pioneer facilities. For each pathway, three sensitivity analyses were conducted. The accompanying Excel spreadsheet includes data and charts summarizing the impact of total distillate fuel yield, feedstock price, and facility scale on SAF MSP.

Table 1: Yield, feedstock price and SAF production scale for each SAF pathway.

Conversion Technology	Feedstock	Yield (wt/wt)	Feedstock Price	SAF production (million L/yr)	
				n <sup>th</sup>	pioneer
FT <sup>1</sup>	MSW	0.31	301 AUD/t	120	20
FT <sup>1</sup>	forest residues	0.18	203 AUD/t	120	20
FT <sup>1</sup>	agricultural residues	0.14	173 AUD/t	120	20
ATJ	starch/sugar ethanol	0.60	1.7 AUD/L	210	35
ATJ	cellulosic ethanol	0.60	2.5 AUD/L	210	35
HEFA	tallow	0.83	1808 AUD/t	160	-
HEFA	rapeseed oil	0.83	1604 AUD/t	160	-
FT	DAC CO <sub>2</sub> , H <sub>2</sub>	0.24	775 AUD/t, 9 AUD/kg	120	-
FT	point source CO <sub>2</sub> , H <sub>2</sub>	0.24	85 AUD/t, 9 AUD/kg	120	-
Pyrolysis <sup>1,2</sup>	forest residues	0.23	203 AUD/t	130	20
Pyrolysis <sup>1,2</sup>	agricultural residues	0.21	173 AUD/t	130	20

<sup>1</sup> feedstock price is for pre-processed feedstock, ASTM approval is pending

The TCI, capital investment per liter of total distillate, and SAF MSP values are presented in Table 2 for both n<sup>th</sup> and pioneer production facilities. The financial viability of SAF production depends on several factors, including ability to secure capital, the scale of which is demonstrated by TCI values, and the ability to sell SAF at a price the market with

tolerate, which can be compared with the SAF MSP. All values exclude monetary incentives but do include a 10% real discount rate.

Table 2: Total capital Investment (TCI), capital cost per liter of total distillate and SAF MSP for each SAF pathway and facility maturity.

Conversion Technology	Feedstock	TCI (million AUD)		Capital Cost (AUD/L total distillate)		SAF MSP (AUD/L)	
		n <sup>th</sup>	pioneer	n <sup>th</sup>	pioneer	n <sup>th</sup>	pioneer
FT <sup>1</sup>	MSW	1809	981	6.0	19.6	2.5	5.1
FT <sup>1</sup>	forest residues	2431	1282	8.1	25.6	3.0	5.3
FT <sup>1</sup>	agricultural residues	2834	1487	9.4	29.7	3.4	7.2
ATJ	starch/sugar ethanol	278	149	0.9	3.0	2.3	2.7
ATJ	cellulosic ethanol	439	205	1.5	4.1	5.2	5.6
HEFA	tallow	420	-	1.4	-	2.3	-
HEFA	rapeseed oil	381	-	1.3	-	2.0	-
FT <sup>3</sup>	DAC CO <sub>2</sub> , H <sub>2</sub>	1705	-	5.7	-	8.5	-
FT <sup>3</sup>	point source CO <sub>2</sub> , H <sub>2</sub>	1500	-	5.0	-	5.0	-
Pyrolysis <sup>1,2</sup>	forest residues	1423	627	4.7	12.5	2.0	3.4
Pyrolysis <sup>1,2</sup>	agricultural residues	1528	652	5.1	13.0	2.0	3.5

<sup>1</sup> feedstock is for pre-processed before arriving at biorefinery, ASTM approval is pending, <sup>2</sup> H<sub>2</sub> and CO<sub>2</sub> are purchased thus the capital costs presented here do not include capital to capture CO<sub>2</sub> or produce H<sub>2</sub>

Abatement costs provide a quantitative metric to compare the financial efficiency of reducing emissions. These values, along with pathway CI values, are listed in Table 3. It should be noted that actual CI values, as well as changes to MSP, will impact abatement costs.

Table 3: CI values and abatement costs for each SAF pathway and facility maturity.

Conversion Technology	Feedstock	CI (gCO <sub>2</sub> e/MJ)	Abatement Cost (AUD/tCO <sub>2</sub> e)	
			n <sup>th</sup>	pioneer
FT	MSW	32.5	770	2100
FT	forest residues	8.3	730	1560
FT	agricultural residue	7.7	860	2220
ATJ	sugarcane ethanol	50.1	1010	1290
ATJ	cellulosic ethanol	24.6	1890	2080
HEFA	tallow	25.6	600	-
HEFA	rapeseed oil	73.4	1930	-
HEFA	Brassica carinata oil	21.7	450	-
FT <sub>1</sub>	DAC CO <sub>2</sub> , green H <sub>2</sub> , wind electricity	7	2660	-
FT <sup>1</sup>	DAC CO <sub>2</sub> , green H <sub>2</sub> , solar electricity	25	3410	-
FT <sup>1</sup>	DAC CO <sub>2</sub> , green H <sub>2</sub> , grid electricity	279	INCREASE	-
FT <sup>1</sup>	point source CO <sub>2</sub> , green H <sub>2</sub> , wind electricity	31	2020	-
FT <sup>1</sup>	point source CO <sub>2</sub> , green H <sub>2</sub> , solar electricity	49	2920	-
Pyrolysis <sup>2,3</sup>		25.7	450	1120
Pyrolysis <sup>2,3</sup>		24.9	460	1130

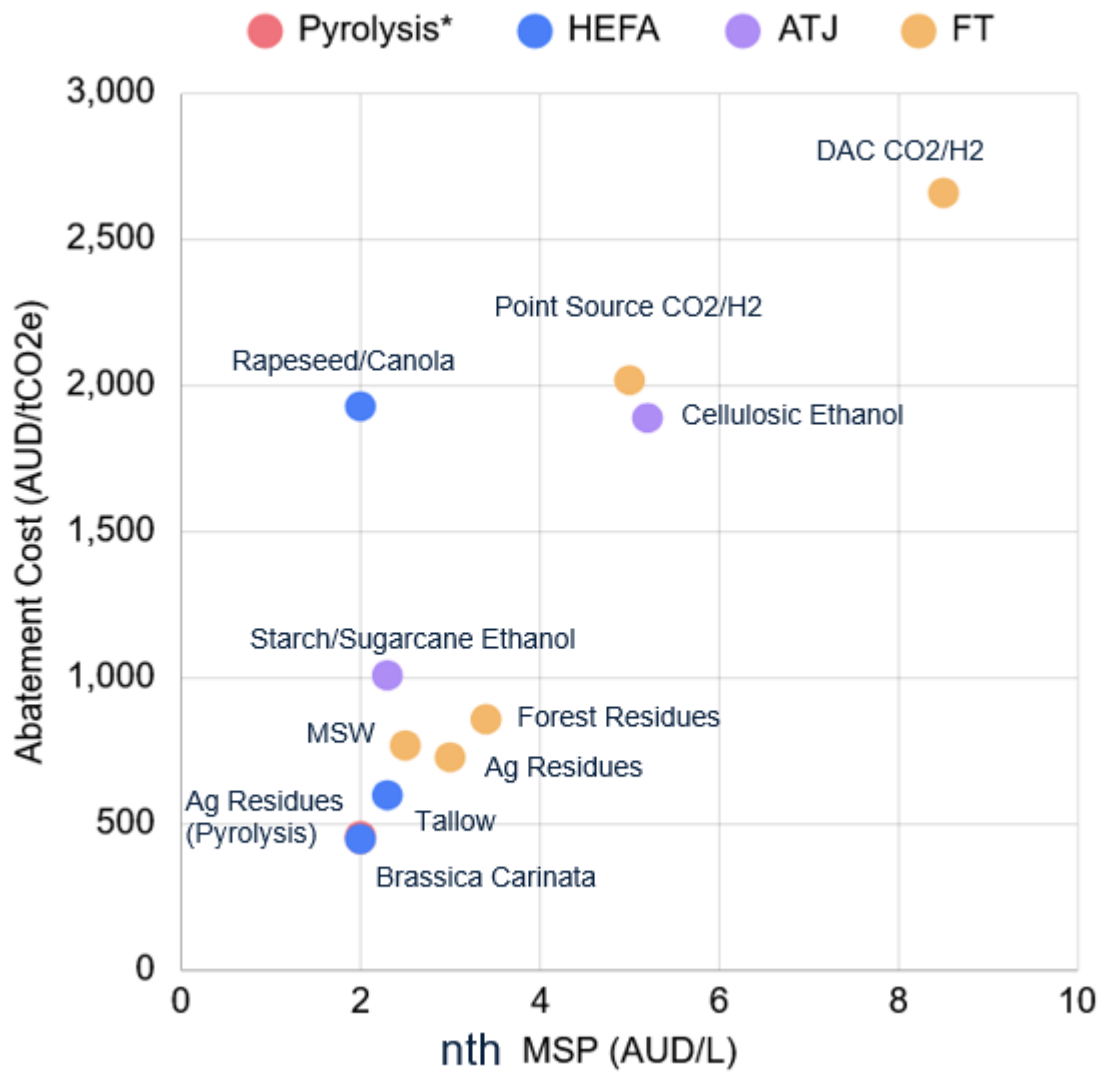
<sup>1</sup> CI value used from ICAO SAF "Rules of Thumb" [13], ASTM approval is pending, <sup>2</sup> CI is from peer reviewed literature

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# Appendix

The Tradeoff Between Abatement Cost and MSP



\*ASTM approval pending