# NZ Battery Project - Biofuel and LNG cost forecast

Prepared for Ministry of Business, Innovation & Employment

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# 1.0 Introduction

The NZ Battery Project is investigating solutions to New Zealand's dry year electricity problem including pumped hydro. For this work, they need to understand the potential for fast-start electricity generation that could operate for several hours, days or weeks, during periods of high electricity demand or low output from wind and solar generation ('green peakers').

These green peakers form an important input into the modelling and understanding of a future renewable electricity system. However, a key input into any modelling is the price and availability of the fuel used. To date the modelling has assumed an open cycle gas turbine running on biodiesel fuel that has unlimited availability and is relatively cost effective ($45/GJ). While this level is typically higher than the cost of petroleum diesel, it is not related to the current and expected market cost for biodiesel. The NZ battery project have concerns around this assumption and would like more detailed price and availability forecasts developed for the period 2035-2065.

Hale & Twomey has previously produced biofuel forecasts for MBIE[1], and the NZ Battery Project has requested that these are updated specifically for a cost to meet the variable demand requirement that would be required for green peakers. This paper backgrounds the biofuels market and explains the build-up of cost for a biofuel to fuel the peakers.

An addendum to the report assesses a price forecast for Liquified Natural Gas (LNG).

Given the period that the forecasts are being developed for (2035-2065) there is a lot of uncertainty particularly given the major energy transition underway with decarbonising the energy supply. These forecasts take that into account with the variation in price, often due to the assumed speed of the transition. As with any long term forecast it is important not to view it in the context of today's market and the short-term movement of prices.

All costs in this report are in New Zealand dollars unless stated otherwise. All conversions to GJ of fuel use the lower (or net) heating value (LHV) of the fuel.

# 2.0 Fuel requirement and infrastructure

By its nature the fuel demand for the green peakers will be highly variable from year to year. In some years (plenty of rain, wind and sun) there is likely to be minimal use, whereas in others the need could be quite substantial. The NZ Battery project have provided three scenarios to cover this wide range.

- Low-use scenario: 200TJ per year of fuel (~6 million litres of biofuel[2])
- Mid-use scenario: 4,000TJ per year of fuel (~117 million litres of biofuel)
- High-use scenario: 12,00TJ per year of fuel (~350 million litres of biofuel)

To give an idea of the scale of this demand, Figure 1 shows the demand requirement against the current national diesel demand, both on an annual and a 6-week use peak demand requirement[3].

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[1] *Biofuel Price Forecast*, Hale & Twomey, January 2021 (also followed by a price forecast assuming a higher petroleum fuel price)

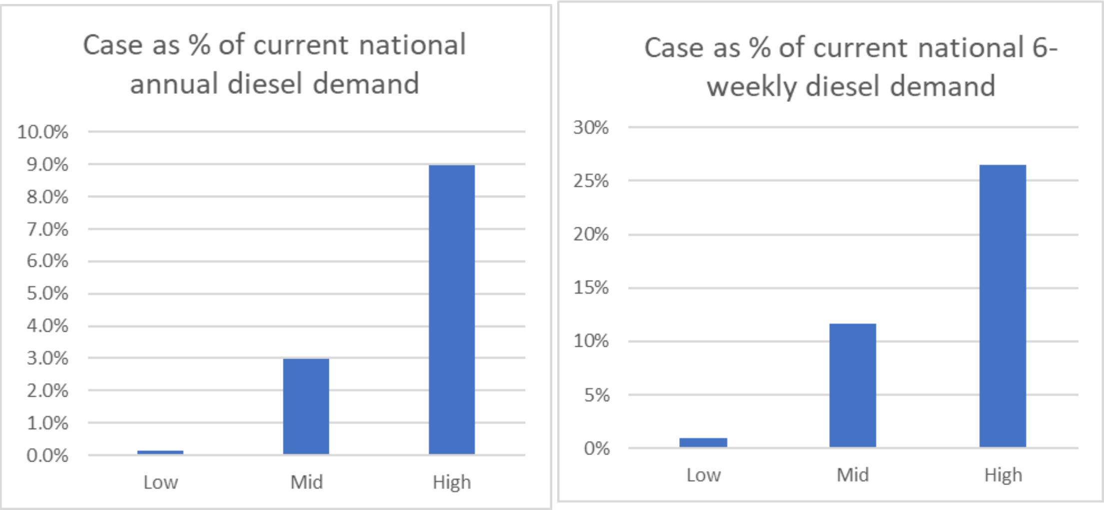
[2] These conversions are based on renewable diesel. Volumes would be much greater for bioethanol.

While the low case is relatively insignificant, even the 6-week mid-case is equivalent to more than 10% of New Zealand's current diesel demand during its peak use, and therefore significant.

The high-use scenario is very significant both on an annual basis (9% of current annual diesel demand) and particularly during peak use (over 25% of diesel demand).

The other requirement set by the demand profile is the infrastructure requirement. The chart in Figure 1 uses a 6-week demand as that is likely to be a measure of the quickest possible resupply[4] timing, assuming an import from the regional market to meet the variable demand.

Figure 1: Fuel requirement as % of current national demand




Given the need to be able to generate electricity when required, our recommendation would be that at least 6-weeks of maximum fuel demand is held in New Zealand, with a portion of that located close to generation. For renewable diesel this means 120 million litres would need to be held which means around 135 million litres of storage capacity would be required[5].

This is a substantial amount. Based on H&T forecasts, the typical total diesel stock currently held in New Zealand is around 220 million litres[6].

Once the market is well developed (high volume), renewable diesel should be able to be delivered on the same type of ships as currently bring product to New Zealand (Medium Range tankers). These typically hold around 50 million litres of product. In the high demand scenario at the maximum 6-week peak use, one ship would meet 2 1/2 weeks of demand.

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[3] Estimated from the chart provided by NZ Battery so reflects 6-week period max use rather than 6x peak weekly demand.

[4] This covers time to go to market, get a cargo and ship and then ship to New Zealand and discharge (about 18-20 days for the actual shipping and discharge). In normal planning cycle this is more likely to take around 9-10 weeks. We note there should be some warning of the need for fuel which should help is arranging resupply.

[5] The tanks need to be larger than the volume of stock held and account for unusable stock in the tank bottoms.

[6] *Fuel Security and Fuel Stockholding Costs*, Report for Ministry of Business, Innovation & Employment, Hale & Twomey, December 2020. Pg. 5

The cost of that storage infrastructure (if newbuilding) would depend on number of locations, size of tanks, etc, but could easily be in the NZ$90-100 million range. We have not included this infrastructure cost in the fuel cost build up as it would be part of the project infrastructure capital cost (along with the peakers) rather than a variable cost with fuel use.

There would also be a cost for holding the diesel which if the storage is full, could be in the order of $250 million (effectively a fuel stockpile cost noting that the renewable fuel does have an alternate use and value so can be sold if not required). Again based on advice from the NZ Battery team this is not included as part of the fuel cost.

Renewable diesel should be able to be held for a long period if stored and monitored to an appropriate standard. However from time to time, stock may need to be refreshed[7]. That means there may be a certain minimum amount that needs to be used over a period of a few years (even if not required for dry year generation) or a means to provide some renewable diesel to the fuels market established, to allow room for replacement stock.

# 3.0 Biofuels considered

## 3.1 Background on biofuels considered

NZ Battery has asked that biodiesel (or equivalent), bioethanol and sustainable aviation fuel (SAF) be considered. While there are other renewable fuels expected to be developed such as biogas, bio-LPG (or bio-DME[8]) these are either not suitable for the purpose (not able to be stockpiled for use) or are likely to be a lot more expensive once the cost of the infrastructure required is included.

Rather than biodiesel, we have built up a cost for renewable diesel. Although it uses similar feedstocks, renewable diesel is produced from a hydrogenation process that provides a drop-in fuel that is chemically similar to petroleum-based diesel. Most investment is now going into these renewable fuels (SAF is produced from a similar process), and our view is by the timeframe for this project (from 2035) renewable diesel would have largely replaced biodiesel production.

Current biodiesel and renewable diesel production has three main feedstock sources - plant based oils, waste streams (primarily used cooking oil), and animal fats. These all have different market prices, with the sources providing the best emissions savings against petroleum fuels having the highest prices (these are waste streams and animal fats). Renewable diesel is also more expensive than biodiesel as a result of it being directly usable in existing fuels infrastructure therefore more valuable to the buyer. The manufacturing cost is also currently more expensive although this may change with scale.

Plant based oils have the issue of competing with food crops (although most major mandates now have rules to avoid this) so some jurisdictions have plans to phase their use out (e.g. Germany by

[7] This was done for the government's diesel stock holding at Napier (for Whirinaki) in the late 2000's.

[8] Dimethyl ether is a synthetic fuel similar in properties to LPG.

2030)[9]. The aviation industry plans are also focused on using only the higher quality (greatest emissions savings) biofuels[10].

The New Zealand Sustainable Biofuel Obligation also intended to require higher quality biofuels, so it is reasonable to set a similar requirement for this project. This cost build-up is therefore based on the higher quality biofuels using more sustainable feedstock (waste and non-food based oils). This does lead to higher price assumptions[11].

Bioethanol is assumed to be from sugar cane as that provides the greatest relative emissions benefit (and as it is an established industry it largely avoids the food competition issue). With declining petrol demand expected over time, bio-ethanol use in the global petrol pool would also decline, leaving volume for other uses.

SAF uses similar feedstock to renewable diesel but requires more processing and typically not all of the feed can be turned into SAF (renewable diesel and renewable LPG also produced). It is currently, and expected to always remain, more expensive than renewable diesel due to both its manufacturing cost and higher demand (there are less alternatives for aviation fuel compared to diesel consumers). Therefore it is not recommended for further consideration for this work although we do provide a price path comparison to renewable diesel.

All these biofuels are 100% renewable in the sense that they are entirely from renewable or waste sources. Although not a requirement for the green peakers, typically these fuels provide an 80-90% lifecycle emissions savings versus petroleum fuels (lower for bioethanol).

## 3.2 Biofuels from woody biomass

The NZ Battery Project is interested in biofuels from woody biomass as that has been the assumption used in the modelling to date. Given New Zealand's large forest resource, woody biomass is frequently proposed for a domestic biofuel industry. [12] Section 5.0 deals with what is required for such as industry to develop (a constant demand rather than variable demand and pricing to the import competition). This section considers international literature on the development and likely costs.

While the ability for biomass to be converted into liquid fuels is well understood technology, the issue has been more about scaling the technology to make it economic. For instance the Fischer-Tropsch process which takes a gasified stream and combines these building blocks into a liquid fuel has been used commercially in South Africa for decades (although with coal as the feedstock, not biomass). While interest in this process is expanding recently with its application to biomass processing[13], it is still very much a niche process due to the high cost.[14]

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[9] Most countries with biofuel mandates have banned use of the biofuels that feedstocks result in deforestation. Plant based biofuels currently are mainly produced from crops such as rape seed and soy, and only include palm oil if certified as sustainable.

[10] See Clean Skies for Tomorrow statement from the World Economic Forum

[11] In the current market that adds US$300-400/tonne to the price (NZ$10-15/GJ)

[12] Scion's 2018 NZ Biofuels Roadmap

[13] See the Sasol website https://www.sasol.com/our-businesses/sasol-ecoft

[14] An initial project planned in Sweden with startup planned in 2026 is for 100,000 tonnes/year (1.25 million litres) https://demoplants21.best-research.eu/projects/info/4032/VEcQZJ

The IEA reviewed a number of these advanced conversion technologies in its Renewables 2022 Report (Table 1). This indicates that bio-based Fischer-Tropsch synthesis has more promise than cellulosic ethanol (which was the expected technical development 15 years ago), but estimated production costs remain at least 50% higher than for conventional biofuel technologies. That said the potential feedstock availability is the big prize if the costs can be reduced.

The IEA modelling assumed (in its accelerated Net-Zero by 2050 case) that the feedstock limitation and cost barriers are overcome in the period from 2030. As noted in Section 5.0 we do not believe the development of such a biofuels route in New Zealand is likely to change our price forecast.

We note that Table 1 provides costs in USD/MJ. This does not appear to be the correct magnitude and suspect it should read USD/GJ.

Table 1: IEA costs on advanced biofuel processes[15]

**Table 4.6 Liquid biofuel production pathways, costs and feedstock potential**

| Technology | Production cost range (USD/MJ) | Feedstock types | Feedstock demand 2021 / total potential |
|---|---|---|---|
| Conventional ethanol, biodiesel, renewable diesel and biojet fuel | 14 – 34* | Conventional biofuel crops such as maize, sugar cane, palm oil, soybean oil and residual or waste oils compatible with FAME and HEFA production. (Production on degraded land, cover crops and intercropping are possible.) | 4 EJ / 12.5 EJ |
| Cellulosic ethanol | 34 – 51 | Agricultural residues, wood residues, dedicated energy crops and other woody wastes. | ~0 EJ / 50 EJ |
| Bio-based Fischer-Tropsch synthesis | 25 – 47 | Woody biomass, agricultural residues, wastes such as municipal solid waste. | |
| Bio-oil co-processing | 26 – 46 | Woody biomass, agricultural residues, wastes such as municipal solid waste. | |

*This is the market price range for crop-based feedstocks. It does not include production on degraded land, cover crops and intercropping.

Notes: Production costs and prices are from IEA Bioenergy TCP (2019) Advanced Biofuels – Potential for Cost Reduction. 2021 feedstock demand is based on IEA analysis. Total potential for conventional feedstocks includes current crop demand (IEA analysis), 2030 crop potential (IEA analysis; IEA [2021], *Net Zero by 2050*), global used cooking oil, animal fat, other agrifood oils, potential for vegetable oil production on degraded land and vegetable oil production via cover crops (Clean Skies for Tomorrow Coalition). Other feedstocks are based on organic wastes, forest and wood residues, short-rotation woody crops and forestry plantations. Biogas and solid bioenergy would compete for these feedstocks (IEA analysis; IEA [2021], *Net Zero by 2050*). Other feedstocks are converted to final liquid biofuel production potential using average conversion efficiency of 50%.

15 IEA Renewables 2022 pg. 143

# 4.0 Biofuel markets

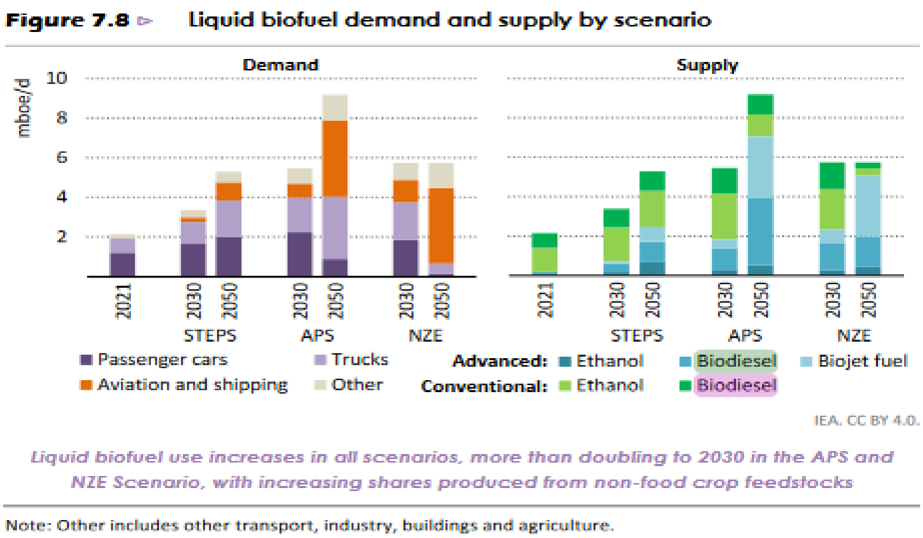
Biofuel markets are already well established globally. Like petroleum markets, trade focuses on main regional centres (e.g. Rotterdam, the US Gulf Coast, Singapore) and product will flow between regions if there is an incentive (e.g. if the market price difference is greater than the cost of freight). The main price reporting agencies (e.g. Platts, Argus) now report regularly (daily) on the biofuels markets along with key feedstocks, resulting with a cross over with those agencies who previously concentrated on agricultural products (e.g. The Jacobsen).

Excluding bioethanol, the major processing areas are Europe and the United States (particularly for renewable diesel and SAF), although Asia has a growing capacity and is a large producer of feedstock so there is scope for processing expansion.

Globally, combined biodiesel and renewable diesel production is currently (2022) around 60,000 million litres annually with about 18,000 million litres of that in Asia (excluding China)[16]. The bulk of this is still biodiesel, although rapid growth is forecast for renewable diesel (and SAF which is has miniscule production by comparison currently[17]). The IEA's World Energy Outlook 2022 shows rapid growth in biofuels in all its scenarios (Figure 2).

Of particular note is the expansion expected from advanced biofuels, both for biodiesel (covering renewable diesel) and biojet, particularly between 2030 and 2050. Both the APS and NZE[18] show an increase of 4-5 times in the biodiesel market by 2030, and many times more by 2050 in the APS (note not as significant in the NZE scenario as that assumes a lot more of the demand has transitioned from liquid fuels to electricity by 2050).

Figure 2: Forward liquid biofuel demand and supply forecast[16]




*Note that 1 mboe/d is approximately 60,000 million litres per year for biodiesel but will be a higher volume for ethanol due to the lower energy content.*

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[16] Data Source, IEA Renewables 2022 (2022 forecast data used).

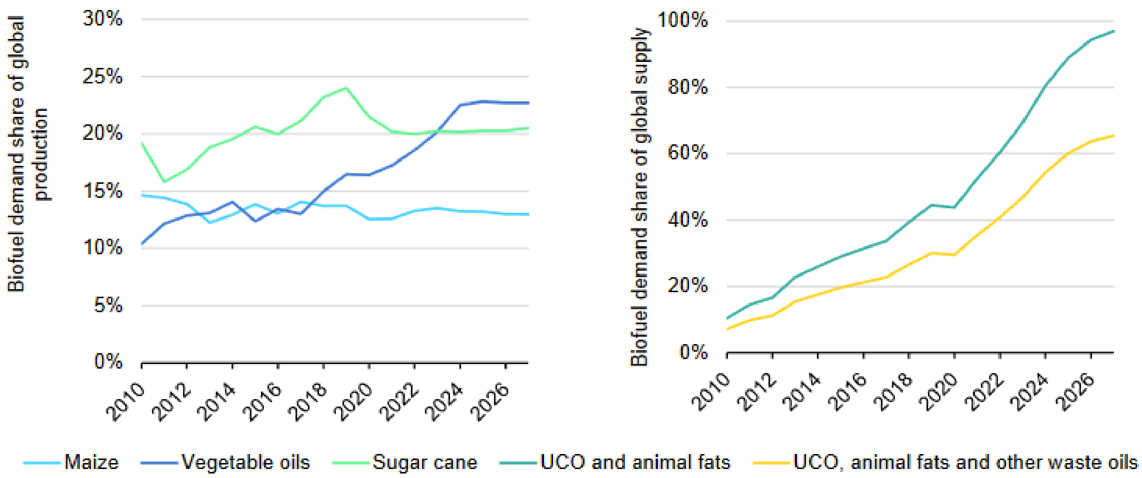
[17] Less than 1,000 million litres globally.

[18] WEO 2022 pg. 344. Note the STEPS scenario in the most pessimistic on transition, only accounting for implemented polices, the APS accounts for announced but not yet implemented policies, whereas the NZE is the modelled scenario to reach net-zero CO2 emissions by 2050. Only the NZE scenario could be regarded a stretch or optimistic outlook.

In the short-term biofuel use can increase from better collection of waste streams (e.g. used cooking oil) and developing supply and processing routes for oils that don't compete with food crops or result in deforestation. The higher prices for biofuels is already providing the incentive for that trend. In the longer term there is a recognition that advanced biofuel routes from waste (producing gas) and biomass need to be developed for high volume use of liquid biofuels due to the supply limitations of the current feedstocks. This is shown in the high potential volume for the bio-based Fischer-Tropsch process in Table 1.

Figure 3: Feedstock demand[19]

**Figure 4.11 Biofuel demand shares of global crop production (left) and wastes and residues (right), main case, 2010-2027**




IEA. CC BY 4.0.

Notes: UCO = used cooking oil. Biofuel demand by feedstock is calculated based on forecast demand, yield coefficients, project feedstock statements, historical feedstock shares and feedstock policy. Ethanol production using maize produces co-products such as feed, corn oil, $CO_2$ and electricity. Maize, vegetable oil and sugar cane production is based on the OECD-FAO *Agricultural Outlook 2022-2031*. Collection potential is based on the Clean Skies for Tomorrow Coalition: used cooking oil, avg. 12 million tonnes; animal fats, 13 million tonnes; and other waste oil, 13 million tonnes.

## Green Peaker demand in the context of the global market forecast

Table 2 shows the demand for the NZ battery medium and high use green peaker fuel in relation to the total forecast biofuel supply, both globally and for the Asian market. The 2035 draw assumes the market has expanded to four times the size in line with the IEA scenarios reflecting more action to be taken to move towards significant emissions declines globally. This should be read in the context that New Zealand's current share of the global diesel market is 0.2-0.3%.

Table 2: Percentage demand on the market

| | **2022** | | | | **2035 estimate** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Global supply** | | **Asia supply** | | **Global supply** | | **Asia supply** | |
| | annual | 6-week | annual | 6-week | annual | 6-week | annual | 6-week |
| Medium-use scenario | 0.2% | 0.8% | 0.7% | 2.6% | 0.0% | 0.2% | 0.2% | 0.6% |
| High-use scenario | 0.6% | 1.7% | 2.0% | 5.9% | 0.1% | 0.4% | 0.5% | 1.5% |

[19] IEA Renewables 2022

The high-use scenario demand would be significant in the context of the current market supply, particularly over a 6-week period. However this is expected to be mitigated by 2035 due to the expansion of market supply (so only a 1.5% pull on Asian supply over the peak demand period as compared to 6% if imposed today). For a relatively short period of demand, we do not think these 2035 demands would put too much pressure of the supply, given the normal variation in the global supply and demand. For instance many countries may be using biofuels in the same way to mitigate sudden requirements for power due to drought (as happens with diesel now). These will all have different timing for needing supply and that variation is supported by storage through the system that can react to changes in demand.

# 5.0 New Zealand biofuel industry

The analysis above assesses the outlook for the global biofuels industry. New Zealand could develop its own biofuel industry too, and there are active investigations, particularly around the production of SAF.[20] However, a domestic biofuels industry will only develop if there is a continuous local demand that can be met economically. This would most likely come from the transport sector (e.g. aviation sector) as manufacturers are unlikely to invest to meet an intermittent demand like that required for the NZ battery project.

Should a domestic industry develop, there might be some but limited flexibility to redirect some flows to green peakers. Ultimately the supply for the incremental demand will need to be imported. Therefore our cost estimates for biofuels assume an import supply.

There might be a marginal saving against this measure should New Zealand become a biofuel exporter due to the need to ship to other markets, however we think a saving is unlikely given the high level of petroleum fuel to be replaced before exports would be considered.

# 6.0 Biofuel cost build up

The cost estimate for biofuel is based on a number of key components.

- How the global biofuels market will develop.
- How competing petroleum fuels will price.
- Costs to land and supply product in New Zealand.

## 6.1 Petroleum fuel prices

Biofuel prices are related to the petroleum fuels they replace, although they are also impacted by other factors such as feedstock supply (and cost), manufacturing cost, and demand—particularly mandates implemented for their use. To date, biofuels (excepting bioethanol) have traded at premiums to petroleum fuels as mandates have created demand that has to be met, which has encouraged investment. The price has risen to a level (well above petroleum fuels) that encourages investment and the incentive (through much higher feedstock prices) to provide greater volumes of feedstocks. An example is the use of used cooking oil for biofuel, which has resulted in much higher prices for the oil, encouraging the collection of much greater volumes of

[20] Sustainable Aviation Fuel in New Zealand, Air New Zealand

this product (rather than going to waste) and thereby providing more supply. As shown in the chart in Figure 3 current prices are already providing the incentive to maximise collection.

Despite the differences, biofuels still trend with petroleum fuel, increasing in price when those fuels increase as the use is the same and customers are either prepared to pay a premium or are forced to through mandates for the biofuel versus the petroleum fuel. That is expected to continue as the market for liquid fuels is so large, although in a scenario with rapid transition to electricity use for transport, petroleum fuels could be expected to decline in price faster than the biofuel equivalent (there is an underlying collection cost for biofuels which limits the likely decline).

Petroleum fuels are highly volatile in price. Even in the last three years, some of the highest and lowest ever fuels prices have been seen (in real terms). 2022 in particular had very high prices following the Russian invasion of the Ukraine. This was particularly true for diesel (and diesel related products like biodiesel), as Russia was formerly a large diesel supplier to Europe and the loss of these volumes led to pressure on the global refining system to replace them.

For a long term forecast like this, it is important not to get caught up in short term market impacts and expect them to continue. Therefore 2022 prices should not be seen as a benchmark for what prices might be like in the future. In the same vein, the very low prices seen in the aftermath of COVID (April/May 2020) are not a good basis for a long-term forecast.

For this work we assume petroleum prices based around a long-term average of US$80/bbl crude oil, which is a level that is seen as sufficient to encourage supply, while not being too high that could lead to rapid demand erosion. US$80/bbl is also around the average price over the past couple of decades.

In time (post-2035) we expect petroleum fuel prices to decline due to the transition to cleaner fuels. However, declining demand will also result in declining investment largely offsetting a price impact. Although we model a smoothly declining trend, in practice it is likely to be highly volatile between periods of low prices where demand drops quicker than expected, and periods of high prices where lack of investment means even the reduced demand causes supply constraints.

## 6.2 Biofuels prices

Biofuel prices have also been volatile, more than doubling in price between the end of 2020 and June 2022[21]. Within that volatility, they continue to trade at a premium to petroleum fuels. That premium tends to increase when petroleum fuels rise in price, although if expressed as a ratio (biofuel/petroleum fuel price) that ratio declines as prices rise. As an example high quality renewable diesel has traded between two and nearly four times[22] diesel prices over the past two years.

For this forecast, we expect biofuels to continue to trade at a significant premium to petroleum fuels. However due to developments in the market, particularly greater scale and more efficient processing[23], we expect that premium to decline slowly. However in the base case forecast renewable diesel price remains at least double the equivalent diesel price.

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[21] June 2022 was the market peak.

[22] Three to four times the price only occurs when petroleum fuels are very low in price. There is an underlying feedstock cost which means biofuels can never decline as much as fossil fuels.

[23] Renewable fuel processing is now leveraging off the most advanced refining technology.

Biofuels are also unlikely to decline in price from 2035 in the same way as petroleum fuels as we expect continued demand as it substitutes for petroleum over that period. We note that the assumption of a continued premium for biofuels above petroleum fuels is in line with international research.[24]

Table 3 covers the key drivers of the biofuel price outlook.

Table 3: Biofuel price influences

| Price Influence | Explanatory | H&T comment on price impact |
|---|---|---|
| Mandates | Mandates for biofuel use are likely to remain the prime driver for demand. These are expected to increase over time both in the volumes mandated and the number of countries implementing them. | Demand due to mandates is expected to result in biofuels continuing at a price premium to petroleum fuel. However mandates are likely to be slowed or suspended if prices get too high (as in 2022) and likely increase if prices drop significantly compared to petroleum fuel. Therefore there is likely to be a price smoothing impact from the ability of governments to vary the mandates. |
| Manufacturing cost | The manufacturing cost and scale, particularly for renewable diesel and SAF, is rapidly developing. | We expect the increasing scale of the processing facilities to reduce the manufacturing cost, and directionally lead to lower premiums compared to petroleum fuel over time. |
| Feedstock supply | Feedstock supply is increasing, but expected to be constrained, particularly for feedstocks that do not compete with food. | Feedstock constraints are expected to keep biofuels expensive relative to petroleum fuels. They also provide a price floor (feedstock price needs to be high enough to encourage collection or to attract from alternate uses). |
| New feedstocks/ advanced biofuels | The forecasts used in this paper (IEA outlook) assume the development of new feedstocks and advanced biofuels manufacture. | If this does not occur in the timeframe assumed, feedstocks will continue to be limited and biofuels will remain a high-priced, niche product (reflective of the high price outlook). Conversely more significant breakthroughs leading to a much greater availability of feedstock would lead to lower prices (in line with low-price outlook). The base case takes a middle ground approach to these developments. |

## 6.3 Cost of supply

There is a cost to ship the biofuel to New Zealand and a logistics and supply cost associated with supply to the plant. As renewable diesel is a drop in fuel, once sufficient volumes are needed it can use the same logistics as petroleum, and hence be more efficient than the separate supply

[24] For example Advanced Biofuels – Potential for Cost Reduction, IEA Bioenergy, 2000, (pg. 10), states "Comparison of the estimates of the current costs of production of the range of advanced biofuels with the prices of the fossil fuels that they aim to replace indicates a significant cost gap of between 12 and 128 EUR/MWh (3-36 EUR/GJ). If the medium-term cost reductions discussed above can be achieved this gap could be narrowed but it will still be significant for many of the pathways." Note this gap equates to NZ$5-62/GJ.

chain required for biodiesel. We also include an infrastructure cost (for receiving infrastructure rather than long-term storage) and a supplier's margin in line with what we would expect for an equivalent diesel supply (recognising the variability of demand). Depending on the siting of the green peakers, this cost may be able to be reduced a little (e.g. direct import into tanks that are part of the infrastructure), although locating a peaker further away from an import port could increase the margin assumed. In total these onshore costs add about $3-4/GJ to the fuel cost. The cost to ship fuel to New Zealand is about half that level.

We model these margins to increase over time, because as the volume of petroleum fuels falls, the costs noted above are likely to increase on a per-litre basis as a function of lower throughputs.

The onshore costs for bioethanol are higher, reflecting a much smaller volume product and the dedicated import infrastructure that would be required.

## 6.4 Price forecasts

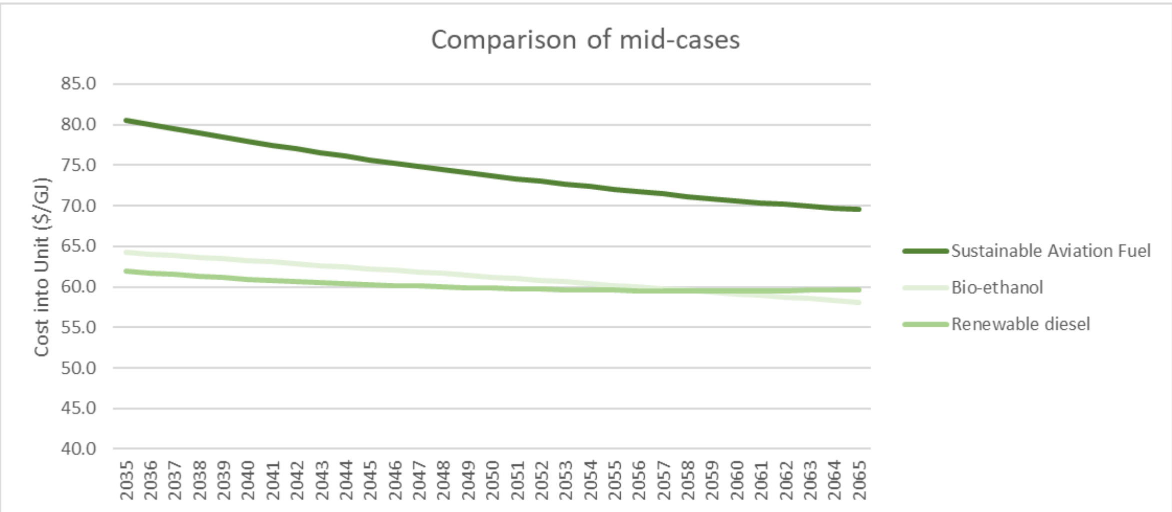
We do not vary the price forecast between the volume cases. While the high-demand case during a 6-week peak demand would put some stress on the supply, it is still relatively small in the context of the overall renewable diesel market expected at that time. Any short-term impact (driving up market prices) is likely to be minimal in comparison to the overall cost of supply.

The output from the modelling is shown in Figure 4 for the period from 2035. While the renewable diesel and bio-ethanol outlooks are similar as a $ cost per GJ, we recommend a renewable diesel fuel as the volume required to meet the GJ demand is a lot lower. This reduces the cost of the infrastructure.

We also think it is far more likely that renewable diesel will be routinely used in New Zealand over this period (from 2035) compared to bioethanol. That provides advantages from supply synergies.

We expect SAF to remain more expensive over the period due to the limited alternatives for the aviation industry, and their ability to pay more than diesel users. However not all production can be directed to SAF so renewable diesel is still expected to be available.

Figure 4: Mid-case outlook for biofuels

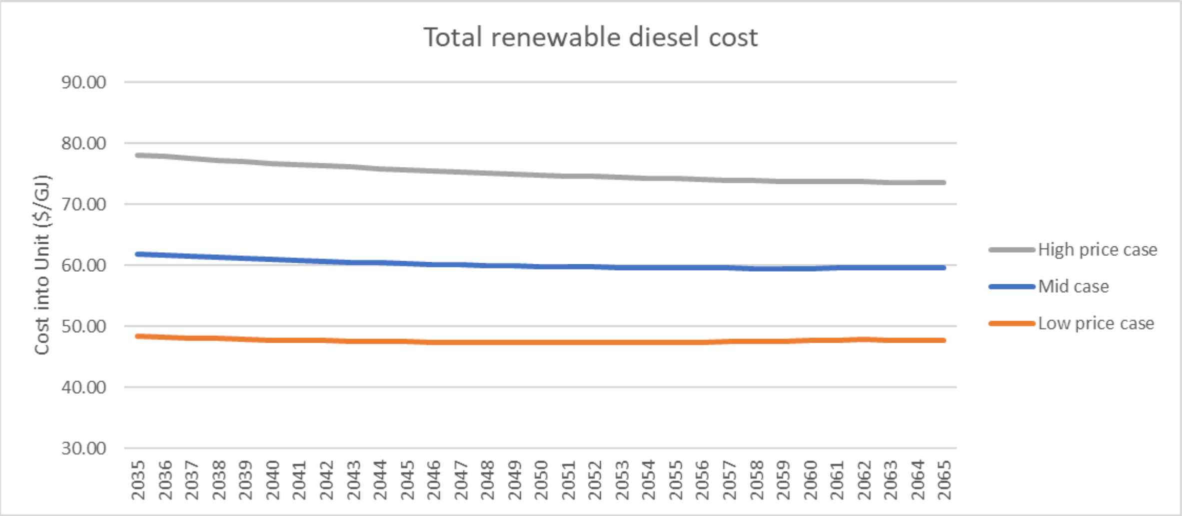



High and low-price cases have been developed for renewable diesel to compare with the mid-case (Figure 5). As noted in Table 3, the high price forecast reflects constrained feedstock supply and limited development of advanced processing routes (e.g. Fischer Tropsch), restricting the total volumes than can be produced. This means that the renewable diesel products will be directed to the highest value uses that can justify paying a substantial premium to petroleum diesel.

The low-price forecast reflects technological breakthrough in feedstocks that can be converted to renewable diesel cost effectively, so they are at the low end of the current forecast cost range. This is expected to rapidly increase the volumes of renewable diesel available. While more substantial, volumes are still expected to be a lot lower than demand for petroleum diesel meaning that even in the low-price case, the renewable diesel is still a lot more expensive than petroleum fuel.

The different renewable cost forecasts reflect different expectations in the development of the biofuels markets. All cases assume a similar fossil fuel price which is around $30/GJ for petroleum diesel.

Figure 5: High, mid and low-price renewable diesel forecast




These trends reflect long term trend averages. Actual prices can and will be volatile from year to year. This volatility on an annual based could easily result in prices closer to either $100/GJ or $30/GJ in a particular year, but those extreme levels would not be sustainable over the longer period modelled here.

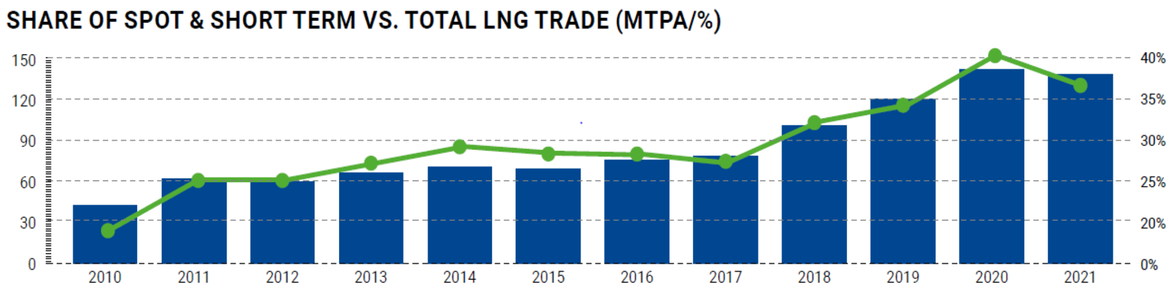
# 7.0 Addendum Report – LNG Price Forecast

The NZ Battery Project also requested a forecast of Liquefied Natural Gas (LNG) for the same 2035 – 2065 period. LNG is a fossil fuel so is expected to be cheaper (excluding the infrastructure required) than biofuels. This price build-up only deals with the delivered cost of LNG to New Zealand, not the infrastructure required to receive, store and distribute (to peaking plants) the gas.

## 7.1 LNG prices

Historically LNG prices were linked to oil markets with very long-term contracts to enable suppliers to commit to the substantial capital required both for the gas production and liquification infrastructure. Rapid development of LNG markets has seen an increased volume trading on a short-term (or spot basis) with benchmarks established to track the price movement. As shown in Figure 6 over 35% of trade is now done on a spot or short-term basis.

Figure 6: Share of spot and short-term trade[25]




*GIIGNL Annual Report 2022 (pg. 41)*

The fuel requirement for the NZ battery project is variable so there is no choice but to look at the spot market for price indications. The spot market is a lot more volatile than long term contracts, particularly over the past few years with COVID (very low) and then the Ukraine invasion (extremely high) impacting spot prices. The benchmark most relevant to this region is the Japan Korea Marker (JKM™) price that reflects the spot market value of liquefied natural gas (LNG) cargoes delivered ex-ship into Japan, South Korea, China, and Taiwan. JKM™ is viewed as a reliable benchmark because it accounts for sales in the biggest importers of LNG.[26]

Over the past decade, the spot prices have had long periods where values were substantially below a typical oil-linked contracts, and periods where they are well above (substantially in the case of 2022).

### Key LNG conversions

The following list provides some of the key conversions relevant to LNG.

- US$1/mmBtu = US$1.055/GJ
- 1 tonne LNG ~ 55 GJ
- 1 m3 LNG ~ 25 GJ

[25] GIIGNL is the International Group of Liquified Natural Gas Importers

[26] https://content.next.westlaw.com/Glossary/PracticalLaw/I3d5e52dc38d611ebbea4f0dc9fb69570?transitionType=Default&contextData=(sc.Default)&firstPage=true

## 7.2 LNG Shipping

LNG ships have got larger over the last two decades, although a move to very large ships (over 200,000 m3) a decade ago appears to have been short lived, with most new LNG tankers around the 170,000-175,000 $m^3$ capacity mark. These hold about 4.3PJ of LNG when at capacity.

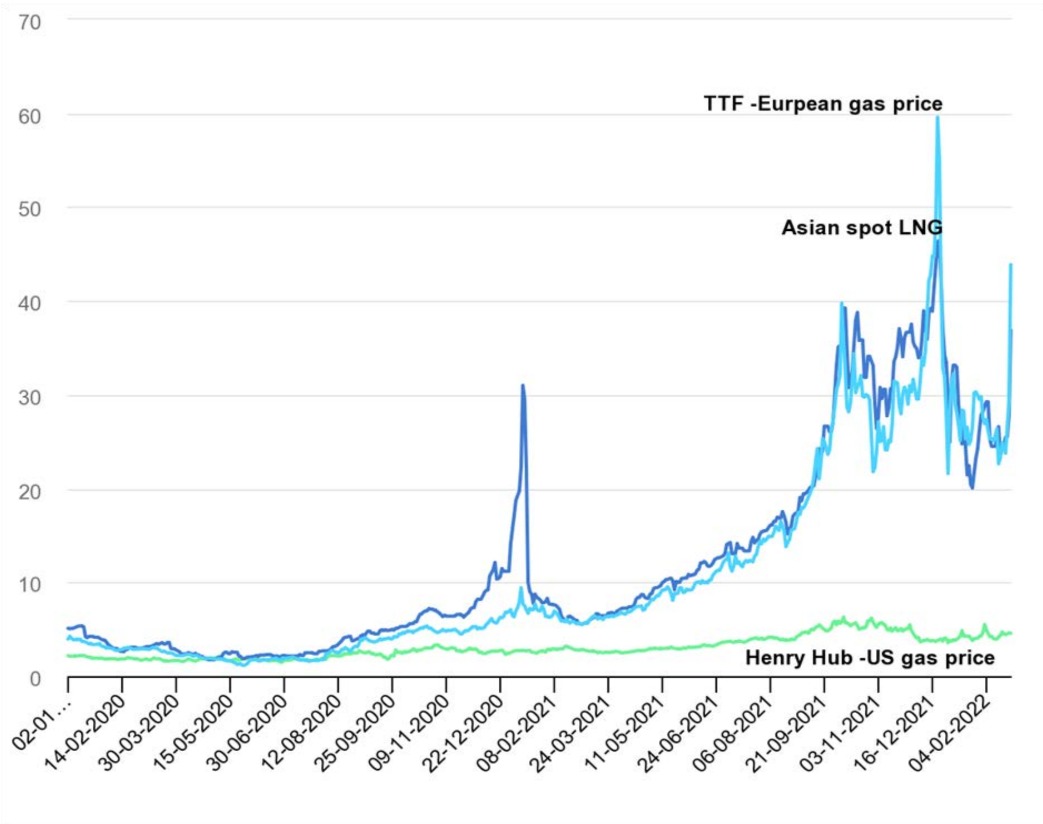
The volume scenarios for LNG as a peaking fuel are a little higher than for biofuel, so assuming a mid-case demand of 4-7PJ/year, this is equivalent to 1 to 2 shipments. The high-level peaking demand of 12-20 PJ/year would require 3 to 5 ship deliveries, with peak demand (if similar to biodiesel case) about 1 shipment every 6 weeks.

There are smaller LNG ships being built but these tend to be dedicated to specific purposes. As a spot buyer, New Zealand would need to ensure it could take the most commonly traded volume on the most common type of ship. Currently that is ships of 170-175,000 $m^3$ capacity.

## 7.3 Forecasting Natural Gas and LNG prices

There are less forecasts for natural gas and LNG prices compared to crude oil due to the difficulty of forecasting prices for what some see as a disjoint market impacted by local factors around delivery of pipeline gas (except for Henry Hub which is the US market which is a very liquid market). The following chart shows how differently sections of the natural gas market responded to the Russian Invasion of the Ukraine.

Figure 7: Natural gas prices in Europe, Asia and the United States, Jan 2020-February 2022 (US$/mmBtu)[27]




[27] https://www.iea.org/reports/russian-supplies-to-global-energy-markets/gas-market-and-russian-supply-2

There are still agencies forecasting prices despite the difficulties. These include the US Energy Information Agency (EIA), the International Energy Agency (IEA), World Bank and other private sector agencies. All these forecasts only go to 2050.

In general the forecasts show:

- Prices are expected to continue to come off the 2022 elevated levels by 2030 (i.e. Europe has adjusted to loss of Russian supply and established long term LNG supply relationships).
- Prices should return to more typical levels (on average) from that point.
- Fast energy transition scenarios generally result in lower price expectations than slow transition scenarios as the use of gas as a transition fuel is for a shorter period.
- The forecast price for Henry Hub (US) is much lower than for Europe and Japan (as would be expected as the US is an export market and the others are import markets).
- Note all price forecasts are 2022 dollars (no inflation assumed).

Specifically:

- Most Henry Hub price forecasts are in the US$3-4/mmBtu range (2022 dollars). They are a little higher in the IEA slow transition (around US$5/mmBtu) but lower in the rapid net-zero by 2050 case (US$2-3/mmBtu)
- While recently the highest price market, European prices are expected to decline below the Asian benchmark, although still more related to those prices rather than the US market, as it will now reflect an LNG import market for much of the supply.
- The Asian benchmark declines to the US$7-10/mmBtu range by 2035 (slightly higher for a slow transition and could be lower for a fast transition due to less use of gas as a transition fuel due to a faster uptake of renewables).

## 7.4 New Zealand LNG forecast prices

For a landed cost in New Zealand we assume a premium to the Asian (JKM) price as it will generally cost more to ship to this part of the world, and you normally expect to pay a premium to attract ships from their normal routes. In theory Australian supply could have a lower shipping cost to New Zealand than to north Asian markets, but we expect the supplier would aim to capture this margin, rather than the buyer. This is particularly true in this case as it is intermittent demand.

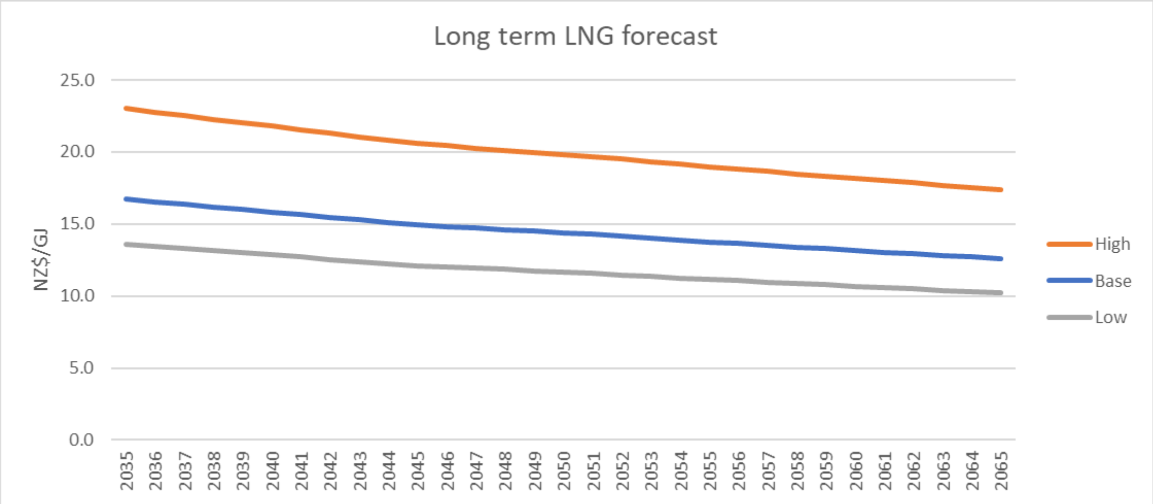
To cover both a shipping premium and an irregular supply premium we add US$1/GJ to the forecasts for Asian LNG supply (a bit higher in the high case and a little lower in the low case).

Our three cases (Low, Base, High) for the long-term LNG price forecast are based on the IEA APS scenarios (all policies implemented). This is their mid-case where more announced transition policies are actually implemented (i.e. Paris commitments), although is not as aggressive as needed to get to net-zero (globally) by 2050. We note the IEA forecasts cover a similar range as the other forecast agencies researched (e.g. World Bank, US EIA) tending towards the higher end of the range of price forecasts reviewed. We add a premium to this price for our Base Case (mid-case) to reflect our view on oil prices (as used for the biofuels forecast) which are a little higher than modelled by the IEA in this scenario.

Our long-term LNG price trend declines in line with most forecasts for LNG prices (to 2050). This is because fossil fuel prices in general are expected to decline due to the transition to renewable fuels. The trend post 2050 is extrapolated based on our crude oil price assumption. However, we add one proviso that if the global market for LNG starts to decline from 2050, prices could rise reflecting lower market demand. Most commentators state that the total natural gas market demand is expected to decline to 2050 due to the move to much greater penetration of renewable fuels, but that lower pipeline supply is partially offset by rising LNG volumes.

An NZ/US exchange rate of 0.65 has been used, in line with the assumption in the biofuels work.

Figure 8: Hale & Twomey LNG price forecast for landed cost in New Zealand




These price estimates will appear low after the prices seen in the last one and a half years, although conversely, they are high compared to the post-COVID 2020 prices. The last one and a half years has seen the most major disruption to gas markets since LNG trade was established in the 1960s, and certainly since LNG spot prices started being routinely reported in the 2000s. Given the scale of disruption in Europe, this period should not be used to model long-term trends, although it does highlight how much prices can move in the short-term.

They will also be low compared to green options as LNG is a fossil fuel. There is no emissions cost penalty included in this price.

### 7.4.1 Local Infrastructure and cost

This report does not need to cover the local costs and infrastructure as NZ Battery Project has alternative sources for that information. However, we make the following comments.

- Given the intermit nature of the demand, a floating storage and regasification terminal (FSRU) is likely to be a lot more cost effective than a land based regassification plant
- Even with a FSRU, the cost will be very substantial on a per-unit throughput basis because of the low throughputs on average. This could well be the most significant part of the fuel cost for peaking units rather than the supply cost into a New Zealand port.
- Unlike liquid fuels, this infrastructure is not easily duplicated, so it is likely that you would only want to import LNG into one location for peaking purposes.
- Marsden Point and New Plymouth were identified as the two more likely LNG import locations during work on LNG import in the 2000s, and Genesis and Contact took an

option for land at Port Taranaki for a future LNG import port. This was dropped after a few years.

- New Plymouth was favoured by those companies for the access to the current pipeline network.
- Marsden Point was discounted for that work due to constrained pipeline networks in that region. However given this LNG supply is intended for use in peaking generation (not pipeline supply), in our view Marsden Point is likely to be more suitable than New Plymouth as it should be easier to consent, it is a bigger and deeper port, and it has the land to site nearby generation (with direct connection to the grid).

In considering the LNG price forecast please note:

- The low, base (mid) and high represent the reasonable range of long-term price averages.
- The annual average price from year to year will be more volatile than that range as has been seen over the past three years.