Ministry of Business, Income and Employment - Hikina Whakatutuki

OPTIONS FOR GREEN PEAKER GENERATION

SUPPLEMENTARY TO NZ BATTERY OTHER TECHNOLOGIES FEASIBILITY STUDY

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	NAME	DATE	SIGNATURE
Prepared by:	LR	1 Nov 2022	LR
Reviewed by:	BB / NM / NS	1 Nov 2022	NTM

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Dear Bridget

Variation - "Green Peaker" Fuel Options Assessment Report

As per your instruction of 9th September 2022 and subsequent discussions, please see attached report where we have considered options for peaking plant using renewable fuels, for deployment circa 2030.

Nigel Matuschka

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150 YEARS IN AOTEAROA

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GLOSSARY

Green Peaker	Peak load generation plant utilising renewable energy sources
Renewable fuel	Fuel derived from renewable (as opposed to fossil-reserve)

ABBREVIATIONS

MCR	Maximum Continuous Rating Text
OCGT	Open cycle gas turbine
SRMC	Short Run Marginal Costs

EXECUTIVE SUMMARY

This report presents basic calculations of fuel requirements for a “green peaker” capability - I.e., a generation capacity of about 800 MW(e) that can be ramped up quickly to cover short-term gaps in solar/wind generation, and operated using renewable fuel. The focus of the study is primarily on fuel options; information on generation plant options is available elsewhere.

It appears to be quite practical to import either ethanol or renewable diesel/biodiesel in the quantities required and although NZ storage facilities would need to be developed, much of the other infrastructure is already available.

Hydrogen/ammonia options are not technically suitable for use in a rapid ramp-rate situation, and other local fuel options require competition with food-crops for resources (grain or oil-crops for ethanol/biodiesel). Ethanol from softwood carries technological and developmental risks. Imported options would however prove the use of renewable fuel types for Open Cycle Gas Turbines (OCGT) usage and would allow time for development of local options in a longer timeframe.

1 PROJECT BACKGROUND

1.1 SCOPE BRIEF

This additional task informs MBIE counterfactual modelling and the inputs for Short Run Marginal Costs (SMRC) for the option of a 100% renewable 'Green Peaker' plant solution being implemented and ready for operation by 2035. MBIE is particularly interested in whether and how SRMC and/or assurance of fuel availability increases with the volume of plant.

2 INFO / DATA PROVIDED TO THE CONSULTANT

- Based on a new greenfield OCGT, similar to Whirinaki for example but running on a 100% renewable fuel.
- Possible fuels could include biofuels such as ethanol, biodiesel, biogas, or other developing energy vectors such as green hydrogen/ammonia
- We understand that MBIE seeks advice from WSP generally around advice and inputs the Opex costs, primarily the variable fuel costs associated with sourcing, transportation and storing of fuel. MBIE already have Capex costs for the generation plant of approximately ~$1250 / kW plus an allowance for low-volume storage (which WSP does not disagree with on the basis of an OCGT without CCS plus an allowance for 'all-in costs'), however this is not the focus of this report.
- Plant assumed to be Open Cycle Gas Turbines (OCGT) such as GE LM6000's (in plant increments of 50 MW)
- A total generation output capacity of about 800 MW (in 50 MW increments spread across 5 sites in NZ)
- Plant not to be operated as a dry year solution, rather a more traditional peaking role is envisioned – providing support for calm/cloudy periods ("dunkelflaute") when generation from both wind and solar is minimal and demand fluctuations occur. i.e., plant with relatively low capacity-factor, random operation.
- Able to start within 1 hour or less, then run continuously for up to 1 week
- 10-12% capacity factor giving a total annual generation capacity of approximately 800 GWh /yr
- Fuel assumed to be sourced from two main tranches, NZ domestically produced, up to an estimated practical volume achievable by 2035, and/or importing 100% renewable fuel. There may be tranches between those as limits of a particular fuel type are met.

3 ASSUMPTIONS MADE

This report is based upon

- Publicly available performance data on gas turbines
- Publicly available information on fuel properties
- Market information provided verbally by a major NZ fuel importer
- Power plant operational information available to WSP
- The green peaker usage has a different operating profile, in terms of energy dispatch, to the NZ Battery. Green peaker energy requirements would be smaller scale but used more frequently, and once switched on would run for periods of days, with the NZ Battery comparatively larger scale but having infrequent operation and once switched on would run continuously for periods of nominally three months.

4 ASSESSMENT / OBSERVATIONS / FINDINGS

4.1 GENERATION PERFORMANCE

The need is for generation plant that can supply power at times of peak demand ("peaker)", hence ramp rate to 100% of Maximum Continuous Rating (MCR) in the shortest possible time. GE quote that the LM6000 has a 5-minute start time and a ramp rate of 50 MW/min, though specific circumstances may dictate longer times. This constrains the options for generation plant to OCGT types. LM6000 (50 MWe) is suggested as an efficient and well-proven type to be considered as a possible reference unit for the purposes of this exercise, and suitable for multiple-unit installations. Other equally suitable plant is readily available. While at least 5 sites are envisaged, locations and distribution of capacities have not yet been considered.

4.2 GENERATION LEVELS

For the approximate generation target of about 800 GWh, installation of about 15 LM6000's would be required. At utilisation of 12%, this would approach 800 GWh or 766 GWh for 11% utilisation.

Variable	Unit	Qty	Notes/references
Unit capacity (LM6000)	MWe	53.0	https://www.ge.com/gas-power/products/gas-turbines/lm6000
Number of units		15.0	
Total generation capacity	MWe	795.0	Target 800, from briefing
Possible hours	h/y	8,766.0	
Utilisation	%	11.0	From briefing
Annual generation	MWh	766,586.7	
	GWh	766.6	
LM6000 OCGT effy, LCV	%	41.4	https://www.ge.com/gas-power/products/gas-turbines/lm6000
Fuel energy required	GWh/yr	1,851.7	
GWH to GJ		3,600.0	http://convert-to.com/conversion/energy/convert-gwh-to-gj.html
GJ/yr		6,665,971.3	

Table 1: Generation basics for a green peaker

4.3 GENERATION OPTIONS

4.3.1 *FUEL OPTIONS*

The project requirement is for a "green peaker" capability – hence only renewable fuel options can be considered.

Possible fuel options are set out below.

Option	Issues
Imported Ethanol	Feasible – options exist
Locally-produced ethanol	Scale effects, some options
Methanol	Offshore market immature
Imported biodiesel	Feasible – options exist
Locally-produced biodiesel from oil-seed crops	Capacity limited by competition for feedstock
locally-produced biodiesel from edible tallow	Capacity limited by competition for feedstock
Syn-Diesel imported	Possible but supply-chain uncertainty
Locally-produced hydrogen	Storage impractical for peaker use
Locally-produced ammonia	Examined within NZBOTFS report.
Imported green ammonia	Review market and availability
Biogas (Methane)	Storage impractical for peaker use

Table 2: Green peaker fuel options

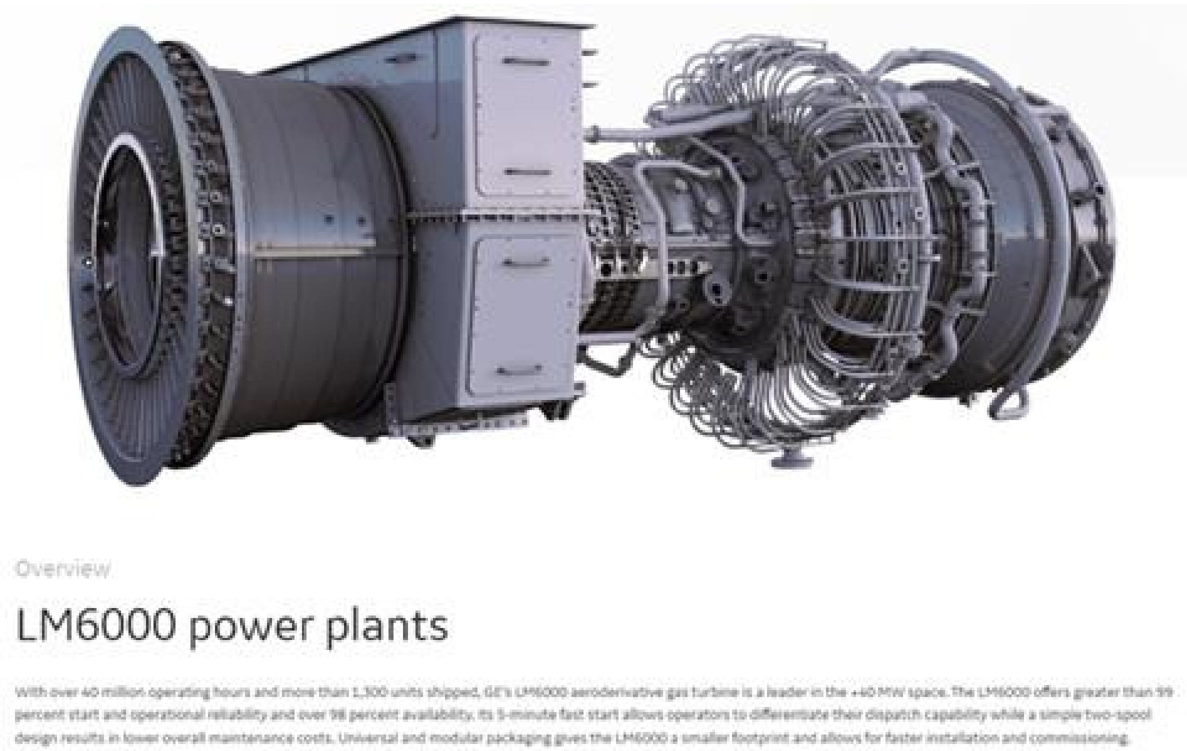
From the list in table 2 above, technical considerations have resulted in several options not being continued for further consideration:

- Methanol is not considered further because it is unclear whether an international market exists, and while much methanol is made in NZ, this is all from fossil fuels. Methanol can be created from pyrolysis of biomass, however this is not considered to be mature technology at large scale.
- The storage of H_2 gas at volumes sufficient for peaker use is considered likely to be impractical for this application. As a consequence, hydrogen gas as a storage medium is not considered further, nor its related alternative of ammonia due to the short term, fast ramping requirement and the uncertainty of availability of GT's capable of directly combusting ammonia (e.g., MHI).
- Biogas is not considered to offer a sufficiently large resource, and the costs of accumulating compressed biogas would be significant. A more detailed assessment of the scale and distribution of this resource is found in the NZBOTFS report,and supports this conclusion.

4.3.2 *GENERATION PLANT OPTIONS*

Lists of OCGT's are from worldwide sources are available. These lists also provide information on fuel options for each.

The proposed LM6000 unit (without generator, infrastructure, or intake/exhaust silencers) is illustrated below.



A typical peaker plant installation (420 MW) is illustrated below

An extensive list of NZ power generation plants, identifying OCGT plant, is available online at <https://en.wikipedia.org/wiki/List_of_power_stations_in_New_Zealand>. WSP's report titled "WSP - 2020 Thermal Generation Stack Report: WSP Project No. 6-P0192.00" provides additional non-public detail including estimated costs.

4.3.3 IMPLEMENTATION OPTIONS TRANCHE 1 – IMPORTED FUEL OPTIONS

4.3.3.1 IMPORTED ETHANOL

Ethanol is currently imported via Port of Tauranga by Gull (NZ). This ethanol is purchased on a mature international market, and sourced from fermented sugar grown in either Queensland, Asia or Brazil. Gull commonly import 1 million-Litre portions for use in their E10 fuels, and so the quantities proposed are likely to be quite feasible as the infrastructure is in place for quantities of this magnitude.

Price and availability trends are likely to be affected by worldwide demands for biofuels, climate effects on sugar production, and national-level regulations such as biofuel mandates. WSP cannot predict the outcome of these, Publicly available predictions (OECD-FAO Agricultural Outlook 2020 - 2029) are only made out to 2029, and it is noted that prices forecasted past 2030 are likely to be influenced by single world events as much as by any current trends. However, we may speculate that population pressures on land use will outweigh economies of scale and pressures of indexation to fossil fuel use; with these caveats, the following table (which does not consider general inflation) could be considered for modelling purposes

DATE	2020	2022*	2030	2065
Reference	100%	104%	120%	150%

*interpolated from raw data

4.3.3.2 IMPORTED BIODIESEL

Biodiesel is produced from plant edible oils and can be imported from Singapore and possibly other places. Renewability levels are believed to be up to 80%, though documentation has not been sighted.

4.3.3.3 IMPORTED GREEN AMMONIA

The existence and maturity of the international market for green ammonia has been explored in the NZ Battery Other Technologies Feasibility Study report. This option is not preferred technically for peaking duty as the cracker is not expected to be suited to rapid start-up and short running scenarios.

4.3.3.4 IMPORTED SYN-DIESEL

Synthetic/renewable diesel (Nesté patented process, distinct from the common transesterification process) is also potentially available internationally and since it is closer in properties to (fossil-derived) diesel can use existing diesel port facilities and storage. However, the available quantities may be limited and the maturity of the market is unknown.

4.3.4 *IMPLEMENTATION OPTIONS TRANCHE 2 – LOCAL FUEL OPTIONS*

4.3.4.1 LOCALLY-PRODUCED ETHANOL

Ethanol is produced by fermenting simple sugars (monosaccharides or disaccharides). NZ's climate does not (yet) encourage the growth of sugar cane, and so our local sources of sugar are lactose (commonly associated with the whey stream generated during cheese syneresis), corn or malted barley - or cellulose that has been enzymatically broken down to simple sugars. Dairy industry lactose availability is subject to variations in Fonterra's commercial activity and so cannot currently be considered to be a reliable source, however options for long term contracted purchase have not been explored. While the processes for producing ethanol from corn or barley are well-known, both crops require use of prime agricultural land and compete for food production and so are not considered a viable long-term solution. The enzymatic breakdown of cellulose (exotic softwood) to simple sugars is possible but is considered technologically immature at present, however interim import options may allow the future development of this option. While waste fruit and other minor sources of sugars exist within NZ, these are considered to be small-scale and not useful for this application.

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4.3.4.2 LOCALLY-PRODUCED BIODIESEL

"Biodiesel" is produced from edible oils, and while at least two processes are mature, the diversion of edible oils to fuel applications is generally considered unacceptable, as is the conversion of additional high-quality land that would be required to support this solution. See Scion 2010 report "New Zealand Biofuels Roadmap Technical Report". Current Australasian canola oil prices are high, suggesting high prices for locally-produced biodiesel, however these prices are significantly affected by the current global impacts of events in Ukraine and specific weather events elsewhere at the time of writing– it is difficult to predict the longer-term trends.

Sapere's 2021 report indicates that this fuel could have a raw cost of between approximately $1.1/L to $2.4/L, which would translate to SRMC prices ranging from $435/MWh to $930/MWh in typical OCGT plant. Other estimation approaches have indicated a range between $450 to as high as $1100/MWh. A target price of somewhat below $500/MWh would seem to offer a useful value for modelling, A wide range (possibly +70% and -30% of the median Sapere Report price) is considered to illustrate the magnitude of the known volatilities and the many unknown price influences.

Edible tallow can be used to produce biodiesel, and this conversion process has been trialled in New Zealand. New Zealand's tallow-biodiesel plant has been shut down due to high tallow prices, that caused the biodiesel to be unable to compete with other available fuels. However, if non-market forces were to incentivise the use of biodiesel, then a tallow-biodiesel conversion option could perhaps pay more for the tallow than other users could offer, The probability of such non-market forces coming into action, and the price point that would allow a NZ facility to divert tallow supplies from other options are not known. If the tallow is currently used in the food chain, then diversion to fuel would require weighing of some ethical as well as commercial issues.

4.3.4.3 LOCALLY-PRODUCED AMMONIA

The option to produce and store ammonia as a Hydrogen carrier has been covered in the main NZ Battery Other Technologies Feasibility Study report.

For the peaker application, this option is not preferred, as a biofuel option is expected to perform better in terms of the fast ramp rates and short duration running required of the “peaker”, whereas ammonia cracking technology and its ability to provide the above ramping operation is relatively unproven. Whilst in the case of the NZ Battery ‘hydrogen hub’ (covered in the main report), ammonia is produced and stored to provide a domestically produced, long term energy back-up; therefore it was important to also consider the same fuel for short term peaking.

4.4 GENERATION COSTS

4.4.1 *FUEL COSTS*

Estimated fuel costs, for 6.7m GJ/year, and indexed to current diesel price, and based on advice from Gull NZ, are as follows. The cost indices (based on diesel) must be considered as very preliminary, No detailed costing exercise has been undertaken, and the indexation to diesel price is unlikely to have medium or long-term validity if diesel prices are significantly affected by other market forces.

Total energy needed	GJ/yr	6,665,971

Fuel type	**LCV MJ/kg**	**Required t/yr**	**Fuel $/kg**	**Annual fuel cost Million NZ$**	**SRMC NZ$/MWh(e)**	**Fuel cost basis % of diesel**
Diesel	42.6	156,478		370	483	100
LFO	40.6	164,186		N/A	N/A	
Ethanol	26.7	249,662		685	893	116
Biodiesel (import)	37.8	176,348		730	952	175
Biodiesel (Local)	37.8	176,348		500	653	120
Syn (green) dies	42.6	156,478		1,295	1689	350
Ammonia				N/A	N/A	

Diesel		
	$/L	2.00
	kg/L	0.84600
	$/t	2,364

Diesel costs have fluctuated very significantly in recent times and a wide margin of uncertainty exists.

4.4.2 *TOTAL OPERATIONAL COSTS*

Short Run Marginal Costs (SRMC) are generally considered to be dominated by fuel costs. The following variable O&M costs from WSP report “WSP - 2020 Thermal Generation Stack Report: WSP Project No. 6-P0192.00 “are reproduced in Figure 1 below, to illustrate this assumption. The SRMC for the purposes of MBIE’s short term peaking market modelling is based on fuel costs, and we again note the current volatility in fuel prices,

Table 3-3 Existing Thermal Generation Plant Data Summary

Plant name	Plant Technology Type	Energy Type	Substation	Project Lifetime (Years)	Capacity (MW)	Availability Factor (AF) (%)	Unit Largest Proportion (ULP) (%)	Baseload (Y/N)	Heat Rate (HHV) (GJ/GWh)	Variable O&M (VOM) (2020 NZD $/MWh)	Fixed O&M (FOM) (2020 NZD $/kW/yr)	Fuel Delivery Costs (FDC) ($/GJ)
Taranaki CC	CCGT	Gas	SFD	50	377	85	100	Y	7,400	5.2	41	0.44
Huntly unit 5 (e3p)	CCGT	Gas	HLY	50	385	93	100	Y	7,400	5.2	41	-
Huntly gas units 1, 2 & 4	ST	Gas	HLY	50	735	83	33	Y	10,900	9.6	70	-
Huntly unit 6 (P40)	OCGT	Gas/diesel	HLY	42	48	87	100	Y	10,525	9.7	19	-
Huntly coal units 1, 2 & 4	ST	Coal	HLY	50	711	78	33	Y	10,900	11.6	82	-
Kapuni	Cogen	Gas	KPA	42	25	85	100	Y	-	5.1	41	-
Hawera (Whareroa)	Cogen	Gas	HWA	42	68	85	25	Y	-	5.1	19	-
Te Rapa	GT	Gas	TRC	42	44	85	100	Y	11,700	4.9	35	0.79
Kinleith	Cogen	Various	KIN	50	40	80	100	Y	-	9.6	70	-
Glenbrook	Cogen	Gas	GLN	50	112	80	100	Y	-	9.6	82	-
Whirinaki	OCGT	Diesel	WHI	25	155	85	33	N	10,906	11.6	23	-
Stratford	OCGT	Gas	SFD	42	210	85	50	N	8,907	9.4	19	0.44
Edgecumbe	GT	Gas	EDG	37	10	80	100	N	11,500	4.9	35	-
Mangahewa	Recip	Gas	SFD	30	9	85	33	N	11,600	14.2	19	-
New Plant Since 2011 Report												
McKee	GT	Gas	MKT	37	100	85	50	N	-	9.4	19	-
Bream Bay	Recip	Diesel	BRB	25	9	85	20	N	-	14.2	19	-
Junction Road	GT	Gas	JKT	37	100	85	50	N	-	9.4	19	-

Figure 1: Recommended non-fuel O&M costs.

4.4.3 FUEL TRANSPORT COSTS

Without any site selection, transport costs cannot be assessed.

5 SUMMARY OF FINDINGS

- At the scale envisaged, the importation of either biodiesel or ethanol to support a "green Peaker" operation is practical and much (though not all) of the required delivery infrastructure is already in place. Additional storage (and associated land) will be needed.
- Fuel importation carries a high risk of supply-chain disruption or of market trends that are outside NZ's control. For an application requiring modest volumes spread relatively evenly, NZ can take advantage of an importation option to avoid/defer internal capex, and can mitigate the supply chain risk with modest levels of stockpiling.
- Costs of imported biodiesel and ethanol have been assessed at a very low level of accuracy. More accurate assessments can be developed as project details are clarified. Several scenarios (e.g. process efficiencies, decarbonisation incentives or increased international transport costs disincentivising exports) could result in NZ biofuel prices trending towards the lower end of price ranges, rather than the upper ends.
- While local production of renewable diesel (biodiesel) is possible, feedstock would compete with local food demands. Previous work in this field has not recommended against this option. Local production of ethanol from grains would likewise compete with food growing and production of ethanol from cellulose is considered to have a significant technical scale-up risk but might be considered alongside import options
- The costs and issues of transporting fuel to peaker-sites cannot be assessed until sites are known.
- In addition to the capital costs of the OCGT installations (which are known to MBIE), the project can be expected to incur capital costs to establish fuel storage. MBIE already have Capex costs for the generation plant of approximately ~$1250 / kW plus an allowance for low-volume storage (which WSP does not disagree with on the basis of an OCGT without CCS plus an allowance for 'all-in costs'), noting that Capex has not been the focus of this report.
- The renewability credentials of imported biofuels will require further investigation to ensure that 100% certified renewable biofuels can be sourced.
- It may be possible to use imported fuel options (ethanol) as a short-term measure to integrate with longer-term development of domestic liquid fuel options.

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