Ministry of Business, Income and Employment - Hikina Whakatutuki

MODELLING ASSUMPTIONS FOR GREEN PEAKER GENERATION

SUPPLEMENTARY TO NZ BATTERY OTHER TECHNOLOGIES FEASIBILITY STUDY

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1	31/03/2023	First Issue – Draft for Review
2	19/05/2023	Updated as per feedback comments
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GLOSSARY

Green Peaker	In the context of the NZ Battery Project a “green peaker” is defined as a fast-start electricity generating plant that can run for hours, days and potentially weeks, using a zero-carbon fuel.

ABBREVIATIONS

BESS	Battery Energy Storage System
Capex	Capital Expenditure
LHV	Lower Heating Value (also called Lower Calorific Value)
MCR	Maximum Continuous Rating
MSW	Municipal Solid Waste
OCGT	Open Cycle Gas Turbine
Opex	Operating Expenditure
SAF	Sustainable Aviation Fuel
SPRINT	SPray INTercooling (of gas turbine)

EXECUTIVE SUMMARY

In the context of the NZ Battery Project, a “green peaker” is defined as a fast-start electricity generating plant that can run for hours, days and potentially weeks, using a zero-carbon fuel.

Following on from 2022’s previous investigations into the option of utilising green peakers and their key engineering parameters, MBIE requested WSP’s assistance to support their understanding of, and modelling assumptions for green peakers, to inform MBIE’s modelling of electricity generation and demand scenarios for the NZ Battery Project.

This work included a high-level review of the potentially available green peaker technology options, including some previously assessed against the NZ Battery Project’s different (long-term, large-scale) energy storage requirements. The potential green peaker options were covered at a collaborative workshop, which considered the relative suitability of each for a green peaking duty. Of these options, an Open Cycle Gas Turbine (OCGT) running on imported zero-carbon fuel was selected as the most suitable technology to provide fast-start, low-utilisation electricity generation plant in the project context for modelling future NZ energy scenarios.

Based on the predicted green peaking plant capacity requirements and rates of utilisation, a standard installation block consisting of 2 x 100 MW OCGT’s is proposed. This will allow the progressive installation (at each of two separate sites) of the first block in 2035, the second in 2050 and the final block in 2065 to achieve the specified 1200 MW total installed generation capacity.

Fuel storage capacity (at each of two separate sites) of 32,000 m^3 is envisaged for 2035, a further 32,000 m^3 in 2050 and the final 8,000 m^3 in 2065 giving a total installed capacity across two sites of 144,000 m^3.

Key engineering and cost estimate parameters for the assumed green peaker plant have been developed and are provided in section 4.

1 BACKGROUND

In May 2022 WSP provided MBIE with an Options Analysis report[i] in which WSP considered the suitability of a wide range of technologies for large-scale, long-term energy storage ("NZ Battery Options Analysis").

In November 2022 WSP also prepared for MBIE, as an addition to the NZ Battery Other Technologies Feasibility Study, an 'Options for green peaker generation' report[ii]. In the context of the NZ Battery Project a green peaker is defined as a fast-start plant that can run for hours, days and potentially weeks, using a zero-carbon fuel. The report sought to identify a technology that met a 'green peaker' brief, considering options for fast-start generation in New Zealand and providing estimated costs for the necessary fuels.

In March 2023, noting and drawing on that previous work, MBIE requested WSP's assistance to further their understanding of the 'green peakers' and associated modelling assumptions. This included a high-level review of the potentially available green peaker technology options. This high-level review was discussed at a collaborative MBIE / WSP green peaker options workshop to consider the relative suitability of each for a green peaking duty, with commentary provided within this report.

The focus of WSP's piece of work was then on determining the fixed capital and variable operating costings of a green peaker plant including storage, infrastructure and generation plant costs, based on a selected technology. A separate 3rd party advisor has been directly engaged by MBIE to provide advice and cost estimates for the acquisition of the fuel (including supply risk, and fuel costs), shipping, port facilities, unloading to port facility and movement to the long-term storage facility (within 25 km).

2 ASSUMPTIONS

2.1 BASIS OF GREEN PEAKER REQUIREMENTS

Key input requirements that have been noted from the MBIE brief include:

Green Peaker capacity (MW) A summary of MBIE's modelling work to date indicates a need for 400 MW of green peaker capacity to be available in 2035, a further 400 MW required in 2050 and a further 400 MW in 2065, totalling an installed capacity of 1,200 MW in 2065. A preference was made to spread the generation plant across nominally two sites in NZ i.e., two sites of 200 MW capacity by 2035 and two sites of 600 MW by 2065.

Utilisation That the green peaker should be assumed to have an average annual utilisation of 5%, which would tend towards the least cost options being likely to be low-capex, high-opex solutions.

Minimum generation duration MBIE's modelling currently includes lithium ion (or equivalent) batteries capable of storing energy (providing grid support energy) for 4-8 hours, and hence the green peaker requirements consider technologies that can provide energy for a minimum of a day.

Start time and ramp rate. A short time to achieve rated power output, and a high ramp rate (rate of change of total output) are essential characteristics of the "peaker" technology.

Technology availability. Technology availability is assessed on the basis of TRL 8 or 9 by 2035. The interval to 2065 is too great to allow useful assessment of the technology readiness level that is likely to be achieved at that date.

2.2 GREEN PEAKER TECHNOLOGY OPTIONS

Potential technology options for a green peaker were explored and discussed at a collaborative MBIE / WSP green peaker options workshop, to assess at a high level the relative suitability of each for a green peaking duty. Below is a summary of the workshop outcomes, and reasoning for selection of imported renewable diesel and generation via an OCGT plant as the basis for the cost modelling.

- **Biogas**. WSP has previously considered the use of biogas (anaerobic digestion of MSW) for generation. While this resource could be used for peaker generation, a review[iii] suggests that that biogas sources are widely dispersed and limited in their ability to provide a continuous fuel source at the scale required for a green peaker (the total is unlikely to exceed 40-50 MW).
- **Flow batteries**. The previous NZ Battery Options Analysis work found this to be a relatively low technical maturity level and a high cost technology option at the scales envisaged. The same findings would apply to flow battery use as a green peaker. It is noted that flow batteries would need to rely on recharging via the capture of excess electricity in a future high-wind and high-solar generation fleet. Flow batteries appear to have potential to be part of a green peaker solution some years into the future, however do not present the most robust and cost effective option in the current context and timeframes required.
- **Compressed air storage**. This was also considered as an energy storage technology in the NZ Battery Options Analysis and was found to be impractical for this purpose. For a green peaker plant requirement, air storage would have less favourable technology readiness and cost effectiveness, and require greater complexity such as the need for additional heat storage / sources relative to other options.

- **Hydrogen.** The process of cracking of hydrogen carriers (such as ammonia) is considered better suited to a longer-start plant and then steady-state operation. It is not well-suited to the highly intermittent operation with rapid-start requirements that is required of a green peaker. In addition, storage of the quantities of molecular hydrogen that would be required for the proposed annual generation is expected to be relatively expensive when compared with other options.
- **Small-scale pumped hydro.** While able to offer green peaking duty, this option is very unlikely to be cost effective being a relatively high-capex, low-opex option compared to other low-capex, high-opex technology options which would be more suited to the low plant utilisation expected.

Based on the above, Open Cycle Gas Turbine (OCGT) technology has been selected to form the basis for costing. This technology is mature, and although efficiency improvements are occurring, the current performance of OCGT machines is considered a reasonable basis for assessing performance and the timeframe of deployment in 2035.

2.3 FUEL PROPOSAL

The OCGT can accommodate a range of fuel options, with considerations summarised below:

Domestically produced biofuels The common interpretation of the Paris agreement[iv] is to prioritize food crops over fuel crops, although we note that fuel crops are not specifically prohibited. It is however likely that fuel from crops can be produced more economically offshore, than from the use of NZ's arable land[v].

Much work has been done in New Zealand to determine the country's capacity for producing biofuels[vi] and that efficiency gains have been made in this field. Research has shown the possibility of producing ethanol from woody biomass, however technical maturity and economic challenges remain and woody biomass to biofuel conversion has not been selected as the preferred option for the purposes of this current exercise. Domestically produced biofuels could be considered for a green peaker solution in the future.

Imported biofuels are traded internationally and produced on a larger scale than is likely for domestically-produced biofuels. Imported options include Ethanol, SAF and renewable diesel/ biodiesel. MBIE's 3rd party advisor for fuel considerations determined that renewable diesel should be considered as the fuel selection for the purpose of this assessment.

Imported renewable diesel for OCGT plant. MBIE's 3rd party is investigating the availability and the cost of imported renewable diesel and applying these costs to the technical installation parameters provided by WSP.

As the information on the sourcing and the importation of renewable diesel is within others' area of focus, for the purposes of WSP's assessment, it is assumed that:

- The imported fuel is obtained from a sustainable source.
- The international supply risks are acceptable
- The market cost risks are acceptable.
- The fuel quality complies with standard fuel specifications[vii]

3 ASSESSMENT

3.1 GENERATION PLANT SELECTION

Current MBIE modelling results have indicated a 2035 demand for approximately 400 MW, increasing to 800 MW in 2050 and to 1200 MW in 2065. As two sites have nominally been proposed, this suggests the use of a 200 MW block at each site initially (to meet the 400 MW capacity) that can then be replicated as needed as the size requirements increase.

The capital cost (per MW) of GT's is known to decrease sharply with increasing size, however a single 200 MW unit would not be preferred for peaking as it may present grid stability issues in the case of trip. It is therefore considered preferable to use 2 units of 100MW each to balance cost against grid stability implications. The capability for remote operation (including start and stop) of the OCGT units is also assumed.

MBIE has expressed a preference for OCGT technology, as it offers a faster start and higher ramp rate than CCGT alternatives. However, it is noted that some CCGT installations can achieve a 30-minute start-up, so if BESS capacity can support the peak demand for over 30 minutes, these options could be considered at a later stage, as could options with diverter stacks allowing start-up in OCGT mode and transition to CCGT mode.

There are a small number of common industrial GTs available. The two most common options for a multi-unit block with capacity of 200 MW are GE's LMS100 and GE's 9F.03. The GE LMS100 offers an 8-minute start time and an excellent open cycle heat rate (42.6% LHV). In addition, it is noted that the LMS100 units proposed are similar to those already installed in New Zealand. The alternative GE 9F.03 offers a longer start-up (30 minutes), lower (34.3% at LHV) efficiency and lower capex but is known for very high reliability.

With the value of selecting a widely-used gas turbine type, the proposed capacity and the importance of rapid start and high ramp-rate, the green peaker capability has been assessed on the basis of 200 MW blocks that each consist of two LMS100[viii] OCGT's. We have not proposed the use of the "SPRINT" (water injected) variant. Many industrial and aero-derivative gas turbines have been successfully run on either renewable diesel or biodiesel, and it is assumed that this will be possible with a selected GT. We note that the efficiency of an OCGT is not likely to be significantly affected by the selection of any common liquid fuel.

The interval between 2035 and 2065 is close to the economic lifetime of typical OCGT installations. A full NPV analysis of a facility, including plant replacement has not been provided.

At least one USA-based company[ix] offers a "... *fully integrated module contains the LMS100PB+ gas turbine with its package and auxiliary systems, balance of plant including the intercooler, driven compression equipment, and control room. The single-lift, plug-and-play module measures 52x21x25 m (LxWxH) and weights just over 1,000 tons....*"

3.2 SITE SELECTION OPTIONS

Site options are influenced by port access, grid access, industrial land availability, proximity of demand and a nominal preference for 2 sites.

- Port and grid access would suggest options at Marsden point (Northport), Auckland, Tauranga, Taranaki, Timaru, and Bluff.
- Demand proximity suggests preference for North Island options.
- Land availability and possible consenting issues suggest that Auckland and Tauranga are less desirable than other options.

Taranaki and Marsden point are therefore initially proposed as the sites upon which costing has been based. These have provided reference locations for the estimation of costs such as land acquisition and consenting. The purpose has been to inform cost estimates only, i.e. has not directly considered or intended to imply the feasibility of these locations.

3.3 FUEL STORAGE REQUIREMENTS

From a high-level assessment of the current modelling results, MBIE's 3rd party biofuels advisor identified a need for at least 120,000 m^3 of green peaker fuel (assuming renewable diesel) to cover NZ's highest-demand 6-week period and proposed the storage volume of 135,000 m^3 to allow some buffer capacity (noting that the biofuel needs are different in all the various scenarios modelled). In terms of the step up in storage needs over time, MBIE have proposed that approximately 40% is needed in 2035 and 90% in 2050 (of the nominal figure required in 2065).

The storage tanks will be likely to be about 8000 m^3 capacity each. This size consideration is based on fuel tanks recently installed at a Timaru site, giving us access to current New Zealand pricing information. Use of 8000 m^3 tanks suggest a final capacity of 144,000 m^3 based on a total of 18 tanks.

Storage of renewable diesel for extended periods will require an ongoing program to remove sediments and any water. The specification of storage and transport facilities will require care to avoid degradation mechanisms that are specific to this fuel. Renewable diesel may also require biocide treatment - however, this is not expected to present a significant cost element. As with other similar fuels, renewable diesel must be stored and transported within specific temperature bands, that are in turn defined individually for the particular type of fuel.

3.4 COST INFORMATION

Cost estimations are based on the following:

- OCGT costs are derived from WSP's GTPro software package[x] and the associated PEACE cost database. The GTPro package is one part of the Thermoflex software suite, allowing modelling of a large range of GT models and configurations, and drawing performance and cost data from a wide range of international sources. An adjustment for NZ conditions has been applied. The OCGT cost item includes unit transformer.
- O&M costs for the OCGT installations are based on typical industry figures and WSP's specific project experience for fixed and variable components of O&M, applied to 2-unit blocks and calculated for the final installed 1200 MW capacity.

- Cost and capacity information for a recent large diesel and petroleum tank farm in Timaru is available and has been used as the basis of the tank farm costs. The level of additional costs that are related specifically to the storage of biodiesel are expected to be relatively small.
- The cost basis for the tank farm (major land-area item) includes land costs: the additional land required for the OCGT's is estimated at 24,000 m^2. The additional cost of the land is likely to below the uncertainty margins for other costs.
- Although a possible installation sequence is considered, no sequencing of capital cost outlay is considered.
- Consenting costs are not known with precision, however both proposed sites have significant industrial installations already and are not considered likely to involve consenting costs beyond the levels allowed for.
- As per the NZ Battery Project Feasibility Study AACE guidelines approach, we have added an appropriate contingency to the base estimate to arrive at the P50.
- Indicatively, the breakdown of gas turbine capital costs are as follows.

GTPro Output

		NZD Million
Project Cost Summary		
I Specialized Equipment		1400
II Other Equipment		60
III Civil		160
IV Mechanical		100
V Electrical Assembly & Wiring		60
VI Buildings & Structures		40
VII Engineering & Plant Startup		60
Gasification Plant		n/a
Desalination Plant		n/a
CO2 Capture Plant		n/a
Subtotal - Contractor's Internal Cost	1880	
VIII Contractor's Soft & Miscellaneous Costs		500
Contractor's Price	2380	
IX Owner's Soft & Miscellaneous Costs		220
Battery Storage System		n/a
Total - Owner's Cost		2600

3.5 OTHER FACTORS

- The economic life of OCGT plant is commonly considered to be about 30 years.
- The capital costings provided by WSP are for a plant sized at total installed electrical capacity and fuel storage capacity that MBIE has envisaged for 2065 but quoted as current NZ dollar values.
- Costings assumed on the basis of being new build / greenfield developments.
- There is limited information available on long term storage of renewable diesel/biodiesel.
- Other selections of OCGT, and/or selections of CCGT options as well as specific site considerations, can be considered when other project parameters are refined.

4 SUMMARY OF FINDINGS

4.1 POSSIBLE INSTALLATION SCHEDULE

	2035	2050	2065
Total installation on each of 2 sites	2 x 100 MW GT's 4 x 8000 m³ storage tanks.	4 x 100 MW GT's 8 x 8000 m³ storage tanks.	6 x 100 MW GT's 9 x 8000 m³ storage tanks.
Total installed generation capacity (MW)	400	800	1200
Total installed fuel storage capacity (m^3)	64,000	128,000	144,000

4.2 GREEN PEAKER COST ESTIMATES & DATA TABLE

Biodiesel fuelled GE LMS-100 OCGTs (1,200 MW installed 2065)	*$ = NZD 2023*
Approximate ramp rate / type of duty	8 min. cold start time, 50 MW/min. ramp rate, emergency ramp speeds of up to 500 MW/min.
Efficient scale of generation (MW)	100 MW units
Capital costs	
Plant costs	OCGT $2,600m (total for 12 x 100 MW GT's) Fuel Storage Facility (including 18 x 8,000 m³ tanks) $200m TOTAL $2,800m
Off sites / receiving terminal, transport etc	Determined by MBIE's external 3rd party
Grid connection costs	$50m
Asset life	30 years
Variable costs	
Specific fuel consumption / conversion efficiency	42.6% net efficiency (LHV)[1] Renewable diesel fuel costs ($ / MWh) to be added as determined by the MBIE's external 3rd party.
O&M	Variable O&M Cost $13.80 / MWh Annual O&M Cost $70m / year

[1] GT efficiency is normally quoted on LCV basis. For the anticipated fuel, the manufacturer's efficiency would translate to about 39.7% efficiency calculated on HCV basis

Overall risk parameters, as pertains to technology readiness and commercial procurement	The GE LMS-100 is a commonly installed OCGT Key risk issues may be related to security of supply of imported biodiesel fuel.

[i] NZ Battery Other Technologies Feasibility Study. Options analysis Report. 6-P0264-RPT-1001-Rev1.2
[ii] Options for green peaker generation. Supplementary to NZ Battery Other Technologies Feasibility Study. 6-P0264.01-RPT-0501-Rev1
[iii] https://www.biogas.org.nz/documents/resource/WB06-biogas-overview.pdf
[iv] https://newsroom.unfccc.int/sites/default/files/english_paris_agreement.pdf
[v] Paris Agreement, https://unfccc.int/sites/default/files/english_paris_agreement.pdf
[vi] Scion "NZ biofuels roadmap" report, https://www.scionresearch.com/science/bioenergy/nz-biofuels-roadmap
[vii] ASTM D6751-20a. Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels, https://www.astm.org/d6751-20a.html
[viii] LMS100, https://www.ge.com/gas-power/products/gas-turbines/lms100
[ix] https://www.bakerhughes.com/gas-turbines/aeroderivative-technology/lms100pb
[x] Thermoflow software package, with PEACE module (Plant Engineering And Construction Estimator) for equipment, BOP, and overall plant preliminary designs, comprehensive cost and labour estimates