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List of documents that have been proactively released		
Date	**Title**	**Author**
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February 2023	NZ Battery Project Indicative Business Case v1.10	MBIE
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In Confidence

Office of the Minister of Energy and Resources

Cabinet Business Committee

New Zealand Battery Project – progressing to the next phase

Proposal

1 This paper seeks Cabinet's agreement to progress the New Zealand Battery Project to its next phase of work.

2 I propose that work on the option of a pumped hydro scheme at Lake Onslow (the Lake Onslow option) should progress to Phase 2a which will involve further technical design and development, policy work and decision-making. The purpose of the next phase of the project will be to prepare detailed designs and undertake policy work to further inform as to the potential operating models of such a scheme and its impact on the market.

3 I also propose that further work should be done on two other options: a Portfolio of other technologies (the Portfolio option) that could address the dry year problem; and, subject to iwi engagement, further preliminary investigation of a potential North Island pumped hydro location at Upper Moawhango.

4 Further work on the project will be aligned closely with the other work in my energy and resources portfolio focussing on the energy transition. This includes the energy strategy, electricity market measures work, gas transition plan and hydrogen roadmap. Alignment of these workstreams will ensure that future critical decisions, needed to achieve our transition targets, are informed by a full understanding of the range of costs and benefits and will form a coherent programme of work.

5 I intend to report back to Cabinet in July 2023 on our developing understanding of the NZ Battery project options and to seek approval to initiate work on a detailed business case.

Relation to government priorities

6 The New Zealand Battery Project relates to the Labour Party's 2020 manifesto commitment to investigate dry year storage solutions to maximise renewable electricity in order to provide a pathway to 100 per cent renewable electricity in New Zealand. It also supports our commitment to reduce greenhouse gas emissions under the Paris Agreement.

Executive Summary

7 The NZ Battery Project has been exploring ways of solving the dry year problem in New Zealand without using fossil fuels and support a pathway to 100% renewable electricity generation. The dry year problem is currently managed in New Zealand by varying thermal fossil fuelled plant, burning gas, coal, and occasionally, diesel.

8 The NZ Battery Project, having run feasibility assessments over pumped hydro at Lake Onslow, and other renewable energy storage options, has prepared an Indicative Business Case (IBC). The IBC identified two preferred options for solving the dry year problem: a pumped hydro scheme at Lake Onslow; and a Portfolio option of alternative technologies, made up of combustion of biomass, new geothermal plant used flexibly, and interruptible hydrogen electrolysis. These two options have materially different characteristics and challenges.

9 The IBC notes that the Lake Onslow option would provide better value for money and provide more certainty over the future of the electricity market. It would have a stabilising effect on the New Zealand electricity market by adding to demand when electricity is abundant, and prices are low and adding to supply when electricity is scare, and prices are high. It is likely that this will net in a downwards pressure on wholesale prices, compared to other scenarios of 100 percent renewable grids.

10 The Portfolio option would retain better option value and could support staging of investment. The three technologies each operate slightly differently, so contribute to managing the dry year in different ways. Like the Lake Onslow option, the Portfolio option could stabilise and put downwards pressure on wholesale prices.

11 The focus on assessing the viability of pumped hydro means that the project team has significantly more information on the Lake Onslow option, than on other options. The IBC notes this significant information asymmetry, if resolved, has the potential to materially change the performance of the Portfolio option.

12 The project team has also identified a pumped hydro scheme at Upper Moawhango as a potential option for further consideration. Its location in the North Island, close to demand, and large storage and generating capacity makes it a potentially attractive option. The NZ Battery Project team is engaging with local iwi on this option before further, if any, is carried on it.

13 I recommend that both the Lake Onslow and Portfolio options progress to further work in 2023, with a Cabinet report back in July 2023. Progressing the Portfolio option will involve optimising the mix of technologies, and delivery models. Next steps on the Lake Onslow option will involve more detailed geotechnical work, engineering design, investigations into delivery models, and environmental and socio-cultural risk assessments. Should it go ahead, further work on the Upper Moawhango option would involve, subject to iwi engagement, economic assessment and further work with the New Zealand Defence Force to understand land-use ramifications.

The problem to be addressed

New Zealand's reliance on hydroelectricity creates a dry year problem

14 New Zealand enjoys an electricity market with a high percentage of renewable generation, by world standards. On average, about 84 per cent of New Zealand's electricity comes from renewable sources, depending on the weather and demand. The grid relies heavily on hydro storage and generation, in the order of 55-60 per cent. Hydro generation is susceptible to variations in inflows within their catchments, which varies how much electricity they can generate year-to-year. New Zealand's

hydro lakes are small relative to their electricity production – storing weeks-to-months of energy (4.5 terawatt hours (TWh) in total). At present, thermal plant, burning coal, gas and occasionally diesel ensure that supply is maintained through annual variations in hydro generation, which is incompatible with our climate ambitions. The NZ Battery Project was established to find a renewable alternative to providing dry year cover.

15 A ‘dry year’ is an extended period of weeks or months when reduced hydro inflows put pressure on the electricity system and result in higher-than-average use of thermal plant. New Zealand needs approximately 3 to 5 TWh of energy storage or equivalent supply-side or demand-side flexibility to achieve reliable and affordable supply in a dry year. For comparison, New Zealand has recently been consuming about 40 TWh per year.

16 2012 is a recent example where a dry year threatened. Cumulative inflows were approximately 3TWh below average heading into winter, though spring brought inflows closer to average for the year. 2012 saw an elevated level of thermal generation in the first three calendar quarters, as the market tried to preserve water, due to the threat of shortage from lower inflows. Coinciding with the threat of a dry year from lower inflows, wholesale prices spiked in late summer and late autumn. There were no public conservation campaigns in 2012, as the market managed the dry year risk with thermal generation.

17 Modelling prepared for the NZ Battery team suggests that there will be a minor increase in total inflows to the hydro lakes with climate change, with about 2% more precipitation falling in the hydro lake catchments compared to today. This is minor compared to the variation between wet and dry years. However that modelling suggests that climate change will provide a small degree of mitigation of the dry year problem, with more precipitation falling as rain and flowing quickly into the lakes, and less as snow which typically melts in the spring before flowing into the lakes. This is important because the effects of the dry year problem are typically realised over winter when demand is highest. However, the dry year will remain a significant problem to be resolved.

The role played by fossil fuels in dry year security

18 Reliable dry year firming requires a large amount of stored energy, to be dispatched over several months in a dry year, where a dry year is difficult to foresee.

19 In recent years the coal-fired Huntly Power Station has played the primary role of managing New Zealand’s dry year problem. Coal is easily storable, and when stocks get depleted, more can be ordered in from overseas. Coal-fired electricity generation has a very high emissions per MWh of electricity generation, roughly double that of fossil gas and approaching ten times the emissions from geothermal generation.

20 Fossil gas-fired generation has also played several roles in the market to date. As well as baseload (a role that is expected to decline rapidly), it plays a role in shorter-term peaking services, such as covering seasonal increases in demand, and daily peaks. Fossil gas plays a role in dry year firming services too, which relies on flexible gas production and underground storage, and sometimes demand response from other gas users.

21 Various industry players (as well as the ICCC and CCC) forecast the retirement of coal from the New Zealand electricity system in the next decade and suggest fossil gas could continue to provide dry year cover and shorter-term peaking services but would not provide baseload supply in competition with lower cost renewable generation. Recent studies, including the Boston Consulting Group's (BCG) report: The Future is Electric suggest that a highly renewable grid of between 95 per cent to 98 per cent can feasibly be achieved without a NZ Battery investment. My officials are engaging with BCG to fully understand the assumptions underpinning the findings of that work and potential impacts of the future pathways set out.

22 Fossil-fuelled solutions to the dry year problem are not in scope of the NZ Battery Project, given the mandate to "maximise renewable electricity in order to provide a pathway to achieve the goal of 100 percent renewable electricity" [CBC-20-MIN-0090 refers]. In any case, the project team considered a base-case scenario with fossil fuelled thermal generation still present in the grid, and assessed against the options with 100 per cent renewable generation. One of the questions to be investigated in future work, alongside other work in my energy and resources portfolio, is to fully understand the comparative costs and commercial viability of gas in providing dry year coverage as it declines in use through the transition.

23 There are, however, some significant challenges in using gas as dry year cover. Maintaining a gas industry for small volumes, that may not in future have anchor customers such as Methanex, may require significant ongoing government support. Maintaining gas for peaking will require ongoing investment in gas storage facilities, peaker plant, and the maintenance, exploration of, and development of new gas fields into the future, all of which have high capital costs, and rely on a high throughput to return on investment. Furthermore, continuing to rely on fossil fuels to firm our electricity grid could tarnish our international reputation.

24 Work is underway in my Energy and Resources portfolio, through the Gas Transition Plan, Energy Market Measures and Energy Strategy work to understand the potential challenges, costs, and any government support or other interventions that may be warranted during the transition to a fully renewable electricity system, with or without NZ Battery. Any further work on the NZ Battery Project will be integrated into a coherent programme alongside these other pieces of work.

Increasing reliance on wind and solar generation will create a calm/cloudy problem

25 Demand for electricity is expected to grow rapidly with the electrification of transport and industrial process heat. Businesses and households reducing their fossil fuel energy use (for example, through switching from petrol or diesel to electric vehicles and coal or gas fired boilers to electric ones), will make a significant contribution to meeting our emissions budgets and climate targets. Commercial Information [redacted] Meeting the demand from this rapid electrification of the economy, along with replacing the around 7 TWh per annum of fossil fuel generation, requires a huge and sustained increase in renewable generation. This is expected to come from private investment in wind, solar and geothermal generation plant.

26 Some renewable plant like geothermal produces a predictable, consistent baseload supply. Others, like wind and solar generation are intermittent in nature and are

susceptible to prolonged periods of calm or cloudy weather conditions. Such calm or cloudy conditions will create an additional security of supply challenge in the New Zealand electricity market as it increases its reliance on those generation types. This emerging challenge is potentially more complex than the dry year problem. A range of work is examining the challenges of transition to a more highly renewable electricity system, including, among other things

26.1 The emissions reduction plan action to investigate the need for, and implementation of, additional market mechanisms and regulation to support affordable and reliable electricity supply during transition to a highly renewable electricity system, which will consider whether and what market, regulatory or other policy measures may be needed to help to address challenges (such as wind and solar intermittency) during transition to an expanded and more highly renewable electricity system.

26.2 The Electricity Authority's Market Development Advisory Group consultation on options to prepare for a renewables-based electricity system, focused on ensuring reliable and efficient operational co-ordination, ensuring effective risk management and efficient investment, strengthening competition and lifting demand side participation in the electricity market.

27 The NZ Battery Project has also assessed the contribution that options for solving the dry year problem can make to solving the emerging calm, cloudy period problem without using thermal generation.

The NZ Battery Project has assessed large renewable energy storage options

28 In December 2020, Cabinet agreed that the objective of the NZ Battery Project was "*to manage or mitigate dry year risk in the electricity system*" and set the following criteria for proposals to be assessed against:

28.1 "provide at least [5,000 GWh] of energy storage or equivalent energy supply flexibility

28.2 provide significant levels of employment for post COVID-19 recovery

28.3 reduce emissions either directly or indirectly through facilitation decarbonisation

28.4 maximise renewable electricity in order to provide a pathway to achieve the goal of 100 per cent renewable electricity

28.5 lower wholesale electricity prices, and

28.6 be practical and feasible."

and noted "that the assessment of any option will take into account wider social, cultural and environmental factors…" [CBC-20-MIN-0090 refers].

29 Since inception, the project has:

29.1 Undertaken a feasibility study into the Lake Onslow option, including initial engineering, environmental, cultural and geotechnical investigations

29.2 Sought and identified other locations in New Zealand where a hydro or pumped hydro scheme of the scale required may be possible, and undertaken desktop studies of three locations

29.3 Scanned and narrowed a list of other storage (or dispatchable energy) technologies that could solve the dry year problem, and undertaken detailed analysis of the three most prospective technologies

29.4 Undertaken substantial market modelling in order to understand the economic and market impacts of the options considered.

30 An Indicative Business Case (IBC) has been completed for the NZ Battery Project and is tabled with this paper. The IBC has been prepared in response to the scale of the problem to be solved, the criteria set by Cabinet and a series of investment objectives. The investment objectives are:

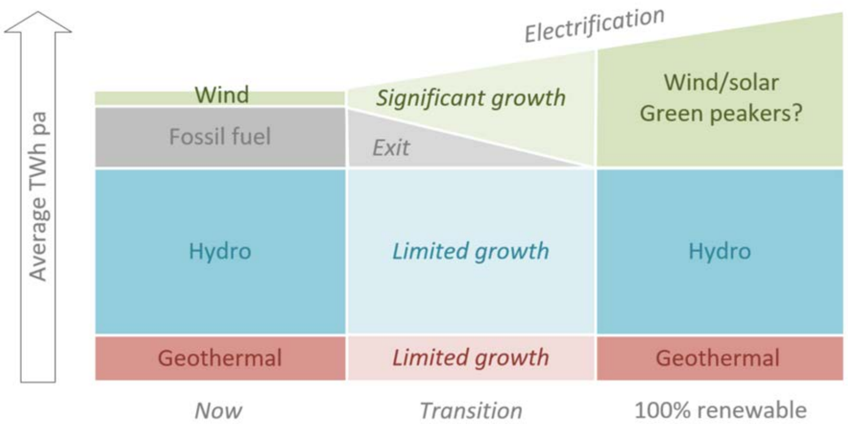
30.1 Objective one: To provide as much security of supply during a dry year as we have today in a 100 per cent renewable electricity system

30.2 Objective two: To put downward pressure on the total cost of electricity supply, compared to a future without NZ Battery, in a 100 per cent renewable electricity system

30.3 Objective three: To accelerate emissions reduction through increased renewable energy.

The NZ Battery Project sits within the context of a wider programme of work on the energy transition

31 The NZ Battery Project complements a wider work programme to address the challenges New Zealand faces as it transitions its energy system and to meet its climate response targets.



32 The figure above provides an illustration of what will be required to achieve the renewable electricity transition:

32.1 over a GW of existing fossil fuel-based generation to be retired or repurposed

32.2 significant investment in and build of new renewable generation

32.3 enhanced transmission and distribution

… while simultaneously:

32.4 managing security of supply and dry year risk

32.5 maintaining affordability and prices at levels that encourage fuel switching.

33 The workstreams noted in paragraph 24 will all address elements of this transition challenge. The NZ Battery project is intended to target point 32.4 above, while considering point 32.5 as wider potential benefits. As work advances across my Energy and Resources portfolio, these workstreams will be closely aligned and coordinated to ensure a coherent, whole of system approach is taken to addressing the energy transition.

34 New Zealand's Emissions Reduction Plan (ERP) highlighted the importance of using our electricity system to help decarbonise our economy. Government is developing an Energy Strategy to address strategic challenges and set pathways for the energy sector. The NZ Battery Project aligns with other transition actions outlined in the ERP to enable us to use our electricity system to meet our emissions reduction goals. The Energy Strategy is in development now and will be undertaking engagement activity throughout 2023.

35 The NZ Battery Project will align with the Energy Strategy and other actions in the ERP including investigating the need for electricity market measures to support transition, and development of a gas transition plan and hydrogen roadmap. This will help to ensure that transition workstreams are coordinated and sequenced effectively. Alignment of these workstreams will also ensure that future critical decisions, needed to achieve our transition targets, are informed by a full understanding of the range of costs and benefits. Specifically, work is underway in my portfolio address transitional issues that may arise before any NZ Battery investment is operational.

The IBC identified two preferred options for solving the dry year problem: the Lake Onslow option; and the Portfolio option

36 Multi-criteria analysis (MCA) has been used through the IBC to identify a preferred option. The MCA found that a Portfolio option of alternative technologies performed marginally better than the Lake Onslow option.

37 The NZ Battery Project team has developed a very strong understanding of the costs, benefits and impacts of developing the Lake Onslow option, proportionate to the stage of the project. The team, however, has run a large study to identify other potentially viable technologies, noting that that option emerged relatively late in the investigation, in adherence to the mandate to "assess the viability of pumped hydro as part of its primary objective, and consider this solution against alternative technologies if they are identified through the process" [CBC-20-MIN-0900 refers]. The Portfolio option was identified once it became clear that non-hydro technologies could not, on their own, provide sufficient storage to address the dry year problem.

38 The information asymmetry between the two options poses challenges in comparing them. For example, the NZ Battery Project has undertaken detailed investigation of the environmental, social and cultural challenges of developing the Lake Onslow option. In contrast, the Portfolio option is not yet tied to specific sites, though elements have broad regions where they could be developed, such as geothermal assets in the central North Island. Because specific sites have not been identified, the equivalent assessments on the local impact (as with the Lake Onslow option) have not been undertaken. There are also some uncertainties about the technologies involved that need to be better understood. These are described further in paragraphs 80 to 82.

39 Further work could therefore demonstrate that the Portfolio option's performance through the MCA either improves or worsens considerably. The uncertainties about the option therefore need to be narrowed, where this is possible, to better inform about its comparative strengths and weaknesses.

40 The IBC results are sensitive to adjustments in criteria and assumptions. For example, the economic modelling baseline assumes that the New Zealand Aluminium Smelter (NZAS) departs the market before 2035, and no similar large demand centre emerges in the South Island. Changing this assumption materially increases the economic value and therefore changes the Benefit Cost Ratio (BCR) scores of the two options. Similarly, applying a 2 per cent discount rate sensitivity has a further impact on those scores, with a significantly more positive impact for the Lake Onslow option (see paragraphs 63 and 83 below).

41 Neither option performs well in the value for money criterion, noting that both have large capital costs early in their lives, with benefits realised over a long horizon. The Lake Onslow option narrowly out-performs the Portfolio option on value for money and affordability criteria. However, it is clear that options could make a significant contribution to addressing New Zealand's dry year problem and providing a secure and decarbonised electricity system.

42 In order to narrow the uncertainties and confirm a preferred solution, I consider that both options should be advanced for further work. This work can progress within the existing appropriation.

The Lake Onslow option

43 The Lake Onslow option would operate by drawing electricity from the grid when it is abundant, to pump water up to the upper storage reservoir. Electricity is abundant in wet years, or windy and sunny periods. That stored water can later be used to generate electricity when the market is under stress, such as in dry years.

44 Work to date indicates that the Lake Onslow option, once fully operational, will reduce the system need for wind and solar capacity, peaking plant capacity and fuel, and short-run batteries when compared with other 100 per cent renewable worlds. Though it is worth noting that in any scenario, there is a need for a very large investment in wind and solar generation over time to meet increasing demand from electrification, and a continuing need for North Island peaking capacity to meet demand reliably during calm cloudy periods.

45 The Lake Onslow option will stabilise and put downwards pressure on wholesale electricity prices. By drawing from the grid to pump when electricity is abundant, and prices are low; and generating when electricity is scarce, and prices are high, the Lake Onslow option will help create a ceiling and floor for wholesale prices and help to reduce volatility. The IBC indicates that this is likely to have a net downwards pressure effect on wholesale prices. The NZ Battery Project's economic modelling to date has been focused on costs rather than prices, so it is premature to draw final conclusions on the magnitude of that downwards pressure. Lake Onslow could also support a strong hedging market, helping market participants better manage risk.

46 The Lake Onslow option will support a pathway to 100 per cent renewable electricity by providing a market for wind and solar energy that would otherwise be spilled, and allowing any remaining fossil fuel plant (such as might be reserved for dry-year security without the Lake Onslow option) to be retired. The project team notes, however, that some short-term firming capacity may be needed beyond what the NZ Battery would offer, to manage calm, cloudy periods when wind and solar generation is lower. Lake Onslow will reduce, but not eliminate, the need for North Island peaking generation – currently serviced by fossil fuelled thermal plant. The P50 estimated deliverable timeline for the Lake Onslow option has commissioning and performance testing completed in Q4 2037.

47 While its operating model is to be determined, the Lake Onslow option will in any operating mode have the effect of increasing low prices and decreasing high prices. This is expected to help intermittent wind and solar, as when they are generating hard, prices tend to be low. Further, the Lake Onslow option is expected to reduce the volatility of prices and provide a physical backing for long-term hedges for the unpredictability of wind and solar generation output. These are both important measures which strengthen the commercial cases for renewable generation investments.

48 The key activities to date, to support the findings in the IBC include:

48.1 An engineering, geotechnical and environmental investigation into the feasibility of the Lake Onslow option focusing on identifying the most feasible scheme design options.

48.2 A programme of detailed geotechnical investigations, including drilling for rock samples in and around Lake Onslow and Teviot Valley, to support the findings of the investigation above, and to identify any fundamental geotechnical risks.

48.3 A range of environmental, cultural and social impact studies around Lake Onslow to identify how these might be affected by the development of a pumped hydro scheme.

48.4 Assessment by Transpower into the transmission and power system implications of the Lake Onslow option.

48.5 Electricity system economic modelling to capture the system cost impacts of different dry-year risk management storage options.

48.6 Wide engagement with the community by officials and Ministerial visits with local landowners and with Ngāi Tahu.

The location of Lake Onslow in the South Island creates some constraints

49 The Lake Onslow option would be a very effective generator, with 1000MW available within minutes and able to be sustained for long periods, and correspondingly a very effective storer of energy, using its speed and capacity to pump whenever prices are low. However, the location of Lake Onslow creates a limitation on the benefit that a pumped hydro scheme there can provide during certain weather conditions. For dry year servicing, the High Voltage Direct Current (HVDC) link is not likely to be a material constraint, given, by it being a dry year, the southern hydro power stations will have less ability to fill the HVDC capacity, and New Zealand needs long-term energy transfer rather than shorter-term capacity support. However, the HVDC capacity will on occasion constrain the Lake Onslow option in its ability to provide firming services for calm and cloudy periods in the North Island, and to draw all of the excess electricity from the North Island during windy and sunny periods.

50 The Battery Project assumes that the HVDC link will be upgraded from 1200MW to 1400MW before the Lake Onslow option is commissioned, as planned by Transpower independently of the Battery project, as a follow-on stage to their recent ‘Net Zero Grid Pathways’ application to the Commerce Commission. This would involve adding a fourth HVDC Cook Strait cable to the existing line. This expansion likely increases the HVDC link to its maximum built capacity.

51 There is a future option to build a second HVDC link, thereby significantly increasing the transmission capacity between the North and South Islands, and significantly improve resilience of the national grid. The increase in capacity would increase the ability for the Lake Onslow option to provide firming services during calm and cloudy periods in the North Island, where it is likely that the majority of wind and solar generation will be. Transpower estimates that building a second HVDC link (e.g. from Lake Onslow to Huntly) would cost approximately $3-4 billion, Commercial [redacted] A second HVDC link, with Lake Onslow operating would materially reduce the need for some additional North Island firming capacity.

Advancing the Lake Onslow option would come with some significant impacts

52 In June 2022, Cabinet noted that developing the Lake Onslow option would come with some significant environmental, cultural and social impacts.

53 The Department of Conservation Te Papa Atawhai (DOC) and Wildlands ecologists have identified a number of conservation risks with raising and varying the lake level at Lake Onslow, some of which may not be able to be fully mitigated, and offsetting or compensation for these losses may be challenging. There are also some gaps in the environmental information, driven primarily by limited land access. Not all those gaps will be filled for the Indicative Business Case (IBC), and further environmental assessments may be required in the future.

54 For example, the Teviot flathead galaxias is a freshwater native fish that is Threatened (nationally critical). Commercial Information [redacted]

Commercial Information [redacted] This leaves them vulnerable to the effects of inundation, physical disturbance, run-off and changes in hydrology. Natural waterfall barriers that protect them from trout may also be compromised. Little research currently exists about translocation of this species, but there may be other mitigation options such as creating waterfalls to protect them from known predators. There are also other threatened species Confidential information entrusted to the Government [redacted] including rare wetland plant species and the Burgan skink, which is threatened (nationally endangered).

55 How to mitigate, offset or compensate for losses will be challenging as these species are both rare and highly localised. Preliminary work has identified nearby possible translocation sites and relocation trials, which would take several years of research and monitoring, would be the next step.

56 Lake Onslow is also an important cultural, social and landscape asset. A cultural values assessment found that there are ancestral, historical toolmaking, and food gathering and mahinga kai sites around Lake Onslow, making it a culturally significant site for mana whenua. The Clutha River/Mata Au has a statutory acknowledgement to recognise the strong ties that Ngāi Tahu has to the river. Furthermore, Lake Onslow is a highly regarded location for local anglers, with notably high stocks of brown trout, which are likely to deteriorate with the raising and varying of the lake level that comes with a pumped hydro scheme. Finally, a pumped hydro scheme with accompanying electrical infrastructure would create a visual impact on the naturalness and uniqueness of the Lake Onslow landscape.

57 Raising the water levels at Lake Onslow to support pumped hydro would inundate private land for which the Crown would need to compensate. Confidential information entrusted to the Government [redacted]

58 Pumping water up to Lake Onslow has biosecurity risks as didymo (rock snot), lagarosiphon (an aquatic weed) and lindavia (freshwater algae) currently present in the Clutha system would likely be introduced to the larger Lake Onslow and Teviot River.

59 The Lake Onslow basin includes large scroll plain wetlands that would be lost. Those wetlands provide important habitat for a range of threatened and at-risk plant and bird species. The specific features of those wetlands mean they could not be offset like-for-like. Officials have done some initial work on exploring other options for compensating for the loss in wetlands by, for example, restoring wetlands in nearby catchments, and elsewhere in Otago. These compensations would be in the order of hundreds of hectares and further work would be required in Phase 2a.

60 Officials are also looking at ways of managing the environmental impact of a pumped water intake on the Clutha River/Mata-Au, including testing the cost and feasibility of fish screens, to limit the damage on aquatic life from moving water at high pressure – both in pumping and generating. An indicative assessment of the environmental effects of the Lake Onslow option is included as part of the detailed engineering, geotechnical and environmental investigation carried out as part of Phase 1.

The Lake Onslow option will involve significant upfront capital expenditure…

61 Table 1 below shows a breakdown of the estimated total capital expenditure required to construct the Lake Onslow option (sometimes referred to as a total out-turn cost). The expected estimate is based on the industry standard P50, which gives a 50 per cent confidence that the final number will be stated value or less and is developed through a quantitative risk assessment process. This estimate accounts for risks and uncertainties that may materialise as the project progresses and uncertainties are resolved. As part of the quality assurance process, the NZ Battery Project had the construction costs and timelines benchmarked (where possible) and independently peer reviewed by industry experts.

62 These numbers represent one potential configuration of the Lake Onslow option: a dam supporting a 5TWh upper reservoir; a 1,000MW generation and pumping capacity [redacted] Negotiations The configuration for Lake Onslow would be optimised through subsequent phases of work and cost lines will vary depending on the final design. There are many variables to the configuration for Lake Onslow, including the size of the upper storage, the capacity of generation and pumping, and the size and location of any lower reservoir. The potential configuration presented here is an option that modelling shows will materially solve the dry year problem, and is representative of a likely development choice. As this is a feasibility level study, this configuration has not been optimised, nor has the optimum configuration been identified. If progressed, the Detailed Business Case will seek decisions on configuration of the Lake Onslow option.

Table 1: Breakdown of expected estimate (P50) of the Lake Onslow option

Construction base estimate[1]	$8,754 m
Risk based contingency @ 31% (P50)	$2,698 m
Escalation @ between 3-5.5% p/a[2]	$4,232 m
Total expected construction capex (P50)	**$15,684 m**

63 The Economic Case finds a BCR for the Lake Onslow option of 0.42, assuming the standard 5 per cent discount rate. This increases to 0.66 with the NZAS, or some similar South Island load remaining; 0.75 where a discount rate of 2 per cent is applied; and 1.12 where these coincide.

64 The Financial Case notes a total project expenditure for the Lake Onslow option of $28.7 billion, over 42 years. This number includes transmission capex, the ongoing operation cost of the asset beyond commissioning, including transmission connection operational costs, whereas the figure above reflects construction capex only. This timeframe reflects the period that has been modelled through the NZ Battery Project, out to 2065. It does not reflect the total life, which is typically more than 100 years for

[1] This number includes system administration capital costs.
[2] Note that the escalation numbers in particular are sensitive to small changes in assumptions.

assets of this nature. The Financial Case calculates the funding envelope over that period as Commercial Information [redacted]

65 I note that this figure is considerably higher than the previous stated estimate of $4 billion for the Lake Onslow option. That estimate was a high level developed by the ICCC, updated from a high-level desktop estimate in 2006, well before the establishment of the NZ Battery project and in advance of the considerable design and geotechnical work that has been completed since January 2021. As indicated above, the revised total figure includes assessment of the all-in costs for the scheme, including escalation, contingency, supporting works such as road and bridge construction, and owners' costs such as land acquisition.

… and require some nearby transmission upgrades…

66 To use the Lake Onslow option effectively, it would be necessary to upgrade transmission infrastructure nearby. Table 2 below shows the total expected transmission upgrades necessary from building the Lake Onslow option.

67 The exact amount payable by NZ Battery will be subject to the transmission pricing methodology (TPM) prevailing during the operational lifetime of Lake Onslow, should it be developed. The Electricity Authority is charged with keeping the TPM in line with its objectives as the industry evolves. What is clear is that not all transmission upgrade costs would be attributable to, and payable by the NZ Battery Project, as the benefits of those upgrades will be realised by other loads and other generators as well as Lake Onslow. In the absence of a definitive dollar value, the project team has, in consultation with Transpower, prepared estimates in the table below.

Table 2: Breakdown of transmission upgrades necessary to support the Lake Onslow option

Required Upgrade	**Expected Estimate allocated to the Lake Onslow option (P50, unescalated),**
A new substation at Onslow connected to the three local 220kV lines, to provide secure connection to the grid	$416.5 m (100%)
A new double-circuit 220kV line from the new Onslow substation to Benmore, plus duplexing of the Aviemore-Benmore line, to improve grid capacity between the Roxburgh region and Waitaki Valley.	$286 m (50% of $572 m)
Improvements to grid protection schemes in the South Island to improve grid stability when Onslow is pumping	$25 m (100%)

68 Longer-term, enhancements to the North Island transmission system are likely to be required in a 100 per cent renewable world in all scenarios. On the work done to date,

the NZ Battery Project team has been able to estimate the costs of these under the Lake Onslow option as in the region of $500 million, it is expected that well under 50 per cent would be allocated to Lake Onslow. It is expected that the Portfolio option would require a comparable level of North Island transmission investment.

… and take approximately 7-9 years to build, following a final investment decision.

69 Table 3 outlines the current estimated time to construct the Lake Onslow option. The P50 schedule has been developed using the same standard and confidence interval as the construction costs above. Note these timeframes assume prompt decision making at each stage to ensure momentum is maintained and that ramp up is possible for the next stage before each decision is confirmed.

Table 3: Breakdown of construction timelines for the Lake Onslow option

Milestone	**Base schedule date**	**P50 schedule date**
Commence Phase 2a	Q1 2023	Q1 2023
DBC Sign Off	Q2 2024	Q4 2024
Final Investment Decision	Q1 2027	Q1 2028
Construction Complete	Q1 2033	Q3 2036
Commissioning and Performance Testing Complete	Commercial Information	

70 This table accounts for pumping water to fill the lake to the minimum point, noting that the intake point will likely be a slightly higher altitude than the current lake level. It does not account for filling the whole lake to full. As soon as the lake level goes above the minimum point, the pumped hydro scheme will be available to supply electricity to the market. The table illustrates the expected P50 schedule, noting that this represents a 50 per cent confidence that the milestones will be met, and is developed through a quantitative risk assessment process. The base schedule column shows the schedule that does not account for risk and uncertainty.

The Portfolio option

71 The project team, with support from the Technical Reference Group (a Ministerial-appointed group representing experts, local leaders, iwi and environmental interest groups), identified a long list of potential technologies[3] and interventions to contribute to solving the dry year problem.

72 After narrowing this list down, the project team commissioned WSP to run pre-feasibility assessments over five broad technology areas. Within these technology

[3] Lithium ion batteries were part of the initial discussion list, but were quickly ruled out as being prohibitively expensive at the scale that New Zealand needs to solve the dry year problem. These batteries rely on quick charge and discharge (intra- or inter-day, rather than across years) to be viable.

areas, WSP's assessment considered the range of options and the feasibility of each being able to supply at least 1TWh of energy to the grid in three months during an infrequent dry year, by 2035. At 1TWh, an option would provide a meaningful partial solution to the dry year problem.

73 WSP identified three technologies that are most feasible for providing large-scale, long-term energy flexibility by 2035: biomass drawing on New Zealand's export log supply chain; new geothermal plant used flexibly; and interruptible hydrogen production stored as ammonia[4]. WSP and MBIE note that each of these technologies have limiting factors challenging their ability to solve the dry year problem by themselves.

74 Noting that each of the technologies could operate only as partial solutions, for the purposes of the IBC, these were combined in the Portfolio option using concept designs established by WSP as part of its feasibility assessment. As assessed, the option could provide approximately 3TWh of energy during the crucial months of a dry year.

The IBC highlights the potential merits of a Portfolio option …

75 The Economic Case identifies that the Portfolio option provides particular benefits in maintaining option value and enabling the possible staging of investments. It, however, scored marginally lower than the Lake Onslow option for its higher price, and poorer performance in providing confidence of security of supply.

76 Work to date indicates that the option, in its entirety, will reduce the system need for wind and solar capacity, and peaking plant capacity and fuel compared with the counterfactual. Based on the concept designs established by WSP, each component of the Portfolio contributes in a different way:

76.1 A biomass generation plant would have stored fuel to allow a few months of continuous operation, and could additionally provide some slower-start peaking services.

76.2 Flexible geothermal could reliably offset a portion of hydro inflow variation for as long as necessary, but cannot start and stop quickly, so has no real peaking capability.

76.3 A hydrogen electrolyser is assumed to feed both a green ammonia export market, and a modest fuel stockpile to supply a generator. The electrolyser, in itself creates a large demand, but is additionally assumed to reduce its operation at times of high prices.

77 The Portfolio option includes some stored fuel, but is not a specialised storage device akin to pumped hydro. Compared with the Lake Onslow option, the Portfolio option needs significantly more wind and solar investment given the electrolyser demand, but significantly less green peaker investment given its assumed North Island location.

[4] WSP also considered flow batteries and compressed or liquid air storage but advised them as infeasible for providing the required amount of storage and generation.

78 The Portfolio option will, like the Lake Onslow option, stabilise and put downwards pressure on wholesale electricity prices. Its dry year and peaking services will put downwards pressure on high prices, though this would be partially offset by upwards price pressure from the hydrogen electrolyser demand. The IBC indicates that the net effect is likely to be downwards pressure on wholesale prices that is comparable to the Lake Onslow option (noting that the NZ Battery project's economic modelling to date has been focused on costs rather than prices, so it is premature to draw final conclusions on the magnitude of price impacts).

79 The project team notes that some short-term firming capacity may be needed beyond what the NZ Battery would offer, to manage calm, cloudy periods when wind and solar generation is lower. The Portfolio option will also reduce, but not eliminate, the need for North Island peaking generation – currently serviced by fossil fuelled thermal plant.

There are some challenges and uncertainties in the Portfolio option

80 The biomass element requires a very large volume of wood redirected from other uses (currently export), to be stored, and later chipped and combusted in a power station. Further work would be necessary to understand the opportunity cost of using that wood in electricity production given the competing demands on our forest resource. Further work will investigate those competing demands and implications for using biomass in electricity generation and will link to the Energy Strategy work in my portfolio and the circular and bio economy strategy in the Economic Development portfolio. Furthermore, there are known the logistical challenges associated with moving, storing and processing it at the volumes necessary to contribute to solving the dry year problem. Also, while biomass is renewable, it is not emissions-free, especially compared to maintaining permanent forest, or using it in applications that sequester the carbon for longer periods.

81 Flexible geothermal as a contribution to the dry year solution requires holding back use of a renewable resource that is (once developed) extremely low cost to utilise. It would involve developing multiple geothermal sites, with electricity production turned down in normal and wet hydrological years, to allow it to turn up to maximum output when a dry year threatens. There is an opportunity cost to this, as our limited geothermal resources may have greater value in a baseload role. Furthermore, the rest of the market needs to believe that this plant will be used for dry year services only, when they make investment decisions about building new generation assets. Further work would be needed to understand what regulatory or contractual settings, and ongoing financial support government would need to create to ensure that these new geothermal generation plants are used in this way.

82 The hydrogen element of the Portfolio option is primarily a demand-response option. It would involve adding a large new hydrogen-producing electrolyser onto the grid that could contribute to a dry year solution by scaling down its output, and therefore electricity consumption during dry years. The plant would convert the hydrogen created from electrolysis into ammonia for storage and transport. Some of the ammonia would be stored long-term and used to fuel an electricity generator in dry years – though only a small proportion to manage the hazard of large-scale ammonia storage. Most ammonia would need to be sold to other users (domestic or overseas). Current markets for green hydrogen are only in their infancy. While there is

momentum and expectation that a market will develop, the timing and nature of that market's development is highly uncertain. It is therefore impossible to predict with certainty whether New Zealand can compete in that market in the long-term, and whether it could tolerate flexible production– including the potential for a prolonged disruption to production during dry years. Also, as this option adds significant demand, without adding balancing storage as Lake Onslow does, it would make the new renewable generation investment needs even more challenging.

However, there are also significant costs to this option, and it is less well understood

83 The Economic Case highlights a BCR for the Portfolio option of 0.4, assuming the standard 5 per cent discount rate. This increases to 0.58 with the NZAS, or some similar South Island load remaining; and 0.54 where a discount rate of 2 per cent is applied; and 0.73 where these coincide. The Financial Case notes a 42-year project expenditure of $49 billion, with a required funding envelope o[redacted] Commercial Information over that period. The Portfolio option has significantly higher projected operating costs than Lake Onslow, but also the potential for greater revenue.

84 As indicated above, there also remain significant uncertainties on the deliverability of each of the elements of the option, some of which may not be able to resolved in the short to medium term. Furthermore, the project team has not assessed operating or ownership models, including the role for the private sector in delivering the Portfolio option. It is likely, however, that there will be a wider range of options for operation and ownership models than the Lake Onslow option, given it involved multiple smaller investments.

I recommend that both the Lake Onslow and Portfolio options should advance to further work

85 I recommend progressing the Lake Onslow option to phase of detailed design. There will be a cost to this. But, given the lead time to develop such an option, advancing work to the next phase will keep momentum up on the option and, should it continue to look prospective, avoid a delay in getting to a final investment decision. There is also a risk of loss of capability and institutional knowledge on that aspect of the project if work is paused.

86 Work to date has failed to identify an alternative renewable dry year solution that is large enough to resolve the problem to the same extent as the Lake Onslow option. The NZ Battery Project suggests that the option will provide considerable benefits to New Zealand in transitioning to and then operating within a 100 per cent world. Given the inherent uncertainties of the Portfolio option, I consider the greater certainty that Lake Onslow would address the dry year problem justifies continuing work.

87 The next stages would involve starting Phase 2a of the Lake Onslow project which would involve more detailed design work with, pending my report back in July 2023, delivery of a Detailed Business Case (DBC). Phase 2b of work on Lake Onslow would involve work towards a final investment decision, starting from Q3 2024.

88 I also recommend that work continues on the Portfolio option, noting that it performed well in the IBC, and could offer attractive option value, and the ability to stage investment. There are, however, unresolved uncertainties that should be worked through to better understand the merits and challenges of the Portfolio option. The next steps would involve further investigation and policy work, including close strategic alignment to other parts of my portfolio, before I report back to Cabinet in July 2023.

For the Lake Onslow option, Phase 2a would involve more geotechnical work…

89 In Phase 1, the NZ Battery Project ran an assessment of the geotechnical risks of building the Lake Onslow option. That assessment was proportionate to the stage of the investigation at Phase 1 of the project, to inform the findings in the IBC.

90 As part of Phase 2a, seeking to inform a DBC, and potentially a future Final Investment Decision, the NZ Battery Project will run a more thorough assessment and narrowing of the geotechnical risks and uncertainties. This will include, for example likely tunnelling conditions, dam foundations and suitability of local aggregate for low cementitious concrete. This involves, among other things, drilling boreholes throughout the areas where significant structures would be developed.

… engineering design…

91 In Phase 1, the NZ Battery Project developed a design of the Lake Onslow option proportionate to the stage of investigation, with its understanding of the associated risks and uncertainties at the time. As the project moves to Phase 2a, and a more detailed understanding of the geotechnical risks emerge, this will necessarily flow to technical adjustments and more detailed design of the scheme.

92 Throughout Phase 2a, the NZ Battery Project will narrow down design options on elements such as dam size and location, powerhouse capacity, lower intake location and lower reservoir location and form.

… advice on procurement and delivery models…

93 The IBC focuses on advice on moving the NZ Battery Project from Phase 1: feasibility assessment to Phase 2a. Part of Phase 2a work will involve developing and advising on options to move the project to subsequent stages, including, but not limited to, procurement strategies and delivery models during the later stages of delivery and construction of the project.

94 Choices in delivery models can affect the risk allocation and management, and delivery timelines of the construction project. Advice to Cabinet at the end of Phase 2a will focus on balancing the benefits, costs and risks to the Crown, of each of the delivery models.

… environmental risk assessments…

95 In Phase 1, the NZ Battery Project ran environmental assessments over approximately half of the likely inundation area at Lake Onslow, to make high level assessments of the environmental risks in building a pumped hydro scheme. Phase 2a will involve a

more thorough assessment of those risks, including further field work at the inundation area.

96 Phase 2a will need to involve a more thorough assessment of the remaining half of the inundation area [redacted] Negotiations The Government will need to continue discussions with landowners of the affected areas, to ensure that appropriate ecological and archaeological surveying can be completed across the whole of the potentially affected area.

97 Further work on water quality at Lake Onslow following flooding will be necessary in Phase 2a, including assessments on how the vegetation and soils surrounding the lake and risks of stratification will affect the oxygen levels of the water. This assessment will also extend to the effects on the Clutha River/Mata-Au downstream of the pumped hydro site.

98 Phase 1 revealed important environmental values [redacted] Confidential advice to Government including the Teviot flathead galaxias, and Burgan skink. Phase 2a will include translocation trials of some species and further fieldwork to better understand their known distributions.

99 Finally, Phase 2a will involve developing detailed advice on the options around mitigating, offsetting and compensation of the environmental values present in and around Lake Onslow.

… social and cultural assessments…

100 In Phase 1, the NZ Battery Project commissioned an Interim Social Impact Assessment report, to highlight the issues and opportunities of developing a large infrastructure project at Lake Onslow.

101 That Interim Social Impact Assessment report found social impacts present through all phases of the work in developing the Lake Onslow option, from initial investigations already undertaken, through to construction and operation. The report also highlighted potential benefits in supporting local social development in the long term through community-, council- and iwi-led initiatives.

102 In parallel to the detailed design being progressed in Phase 2a, more work on that Social Impact Assessment will be commissioned to actively manage impacts and explore ways to maximize benefits to affected communities. This includes factors like workforce impacts, and accommodation services for workers.

103 Further work would also need to occur with mana whenua including involvement in archaeological fieldwork and preparing a cultural impact statement.

… and would support the drafting of a Detailed Business Case, to be delivered in mid-2024.

104 I will provide an update in July 2023 on progress on the Phase 2a when I will seek approval for the NZ Battery Project to consolidate its advice into a DBC. This report back will include advice on alternative technologies, and findings on pumped hydro at Upper Moawhango outlined in more detail below.

105 The DBC will, among other things, give a proportionately more precise assessment of costs, construction timelines and risks; and propose options for managing those risks. I expect to report back to Cabinet in mid-2024 with the findings of the DBC, to seek further decisions on progressing the NZ Battery Project.

Negotiations

[redacted]

For the Portfolio option, work would involve optimising the mix of technologies and policy work to establish how it would be delivered

107 The Portfolio option appears to be similarly costly and complex to a pumped hydro solution, given it involves development of multiple plant, deployed at a scale that is ambitious for these technologies and redirecting or establishing potentially complex supply chains. However, due to timing, the Portfolio option assessed in the IBC was not optimised to identify the size and configuration that could, in reality, be delivered with the best mix of outcomes. It is possible that just one or two of the technologies within the portfolio, in combination with excess wind and solar generation, could have greater net benefits than indicated so far in the IBC.

108 Given this uncertainty, I recommend that the NZ Battery Project continues work on the Portfolio option to better understand its full potential. I note, however, that because elements of the option rely on undeveloped technology and markets, they carry unresolvable uncertainty. Ultimately a decision to rely on the Portfolio option to resolve the dry year problem will require a tolerance for this uncertainty.

109 The next steps on this work would include developing an understanding of how a delivery model would work, in a manner that does not deter the scale of new renewable market generation investment that New Zealand needs. The Electricity Market Measures work is due to progress in early 2023 and presents an opportunity for synergies with the Portfolio option.

110 I will report back to Cabinet in July 2023 with an update on work on this option.

For both options the Government will need to engage the market

111 The NZ Battery Project will engage with market participants on:

111.1 options around governance and operation of large, pumped hydro in New Zealand. That engagement will support advice on regulatory or contractual arrangements and the parameters of its operation, to ensure that the asset, if built, creates the maximum value for New Zealand, without negatively affecting investment incentives on the rest of the market.

111.2 delivery options for the Portfolio option.

112 I propose that this engagement is targeted, and focuses on current and prospective New Zealand generators (both gentailers and independent generators), retailers, and consumer groups, the Electricity Authority and Transpower.

Iwi engagement is underway on a North Island pumped hydro site

The NZ Battery Project searched for alternative sites for a pumped hydro scheme

113 The NZ Battery Project commissioned NIWA to run a detailed scan over the country's waterways to identify potential sites for a pumped hydro scheme, with the potential for storage of at least 1TWh of energy stored as water.

114 In addition to Lake Onslow, that scan identified two sites: at Upper Moawhango and Taruarau River both in the central North Island. The project team also identified Lake Pukaki as potentially being suitable for expansion as a traditional hydro asset. The NZ Battery Project then commissioned Stantec to run a desktop assessment of the three hydro sites above. The Stantec work investigated the engineering, geological, environment and cultural aspects of each of the three sites.

115 Further work on Taruarau River and the expansion of Lake Pukaki were ruled out, noting that both options were too small in storage or generation capacity to have a meaningful effect on the dry year problem, and carried less confidence in deliverability from the initial, high-level desktop assessment.

Pumped hydro at Upper Moawhango shows some potential

116 The NIWA scan identified a series of basins at the head of the Moawhango river, at the southern end of the Kaimanawa ranges, that could support a pumped hydro scheme. Stantec ran a preliminary, desktop-level assessment, and concluded that the site had the potential to support up to 2.75TWh of additional storage capacity and 570MW of additional generation, subject to field studies to run geotechnical and engineering feasibility assessments, but was not of sufficient detail to confirm the feasibility of the development, or otherwise. This large potential capacity, combined with its favourable location, close to demand centres and north of the HVDC link, makes it a potentially attractive proposition.

117 However, if built, pumped hydro at Upper Moawhango would interact with the existing Tongariro Power Scheme, the effect of this on its benefits is not yet known. Detailed modelling of water flows would reveal the potential value of the scheme, including how it would interact with the existing Tongariro Power Scheme. That detailed modelling has not been completed, pending agreement with local iwi.

The NZ Battery Project does not have enough understanding of pumped hydro at Upper Moawhango to rule it in or out

118 The work to date has established that a pumped hydro scheme at Upper Moawhango has the potential to make a meaningful contribution to solving the dry year problem. However, work at this stage does not provide enough information to rule it in or out.

119 The original development of the Tongariro Power Development Scheme in the middle of the twentieth century remains a source of grievance for iwi with interests in the area. Grievances relate to the limited consultation by the government of the day and the ongoing environmental, cultural and spiritual effects caused by reduced water flows into the sacred awa that are diverted into the scheme. The failure to consult with certain iwi has been acknowledged as a breach of the Treaty of Waitangi. The Ngāti Tūwharetoa Claims Settlement Act includes formal recognition of the grievances that the Tongariro Power Scheme caused for Ngāti Tūwharetoa:

> *The Crown acknowledges that the construction and operation of the Tongariro Power Development Scheme—*
>
> *(a) has had a destructive impact on the cultural and spiritual well-being of Ngāti Tūwharetoa; and*
>
> *(b) has mixed the waterways of Tongariro Maunga with one another, and is considered by Ngāti Tūwharetoa to be inconsistent with the mauri of those waters; and*
>
> *(c) has caused distress and remains a significant grievance for Ngāti Tūwharetoa.*

120 In September 2022, Adrian Rurawhe MP and I met with iwi local to Upper Moawhango, including Mōkai Pātea and Ngāti Rangi. At that hui, I undertook to not proceed with further work until iwi agreed a way forward. The Government has not yet agreed that pathway forward with iwi. Subject to iwi engagement and agreement on that pathway forward, the next step for pumped hydro at Upper Moawhango would be for more detailed hydrological and economic modelling to be undertaken, to assess its merits.

Early desktop assessment also revealed other challenges

121 Developing a pumped hydro scheme at Upper Moawhango would flood in the order of [redacted] Negotiations

122 Stantec's assessment of pumped hydro at Upper Moawhango noted that there are likely important environmental values present at Upper Moawhango, including rare wetlands and species and predominantly native vegetation. Any further work on feasibility should make appropriate environmental assessments.

123 Stantec also noted that a large portion of the potential scheme would flood New Zealand Defence Force (NZDF) land. NZDF informs that a detailed study would need to be completed to gain a full understanding of the impacts on the NZDF, its facilities and training environment. [redacted] National security or defence At this stage it does not consider there would be viable alternatives to replacing the area [redacted] Negotiations

Negotiations [redacted]

124 National security or defence [redacted]

I will report back to Cabinet in July 2023 with an update on work on pumped hydro at Upper Moawhango

125 A better understanding of this option is required. My officials will continue to work with the NZDF to better understand the impacts of such a scheme. They will also continue to engage with iwi on the option. If iwi agree the project team will undertake economic assessment to better inform whether the option shows adequate potential. I will report back to Cabinet with my proposed next steps on Upper Moawhango in July 2023, along with an update on studies on the Lake Onslow option.

126 Advancing this option then to the next step would involve taking it through a phase 1 feasibility assessment, similar to that just completed for the Lake Onslow option.

The IBC compared the options to a counterfactual world of 100 per cent renewable generation

127 The IBC compares the options above to a scenario with 100 per cent renewable electricity, with no large-scale battery intervention. This scenario is characterised with a large wind, solar and geothermal generation investment, and the inclusion of a carbon-neutral, dispatchable electricity generator with a high short-run marginal cost – referred to as "green peakers".

128 Green peakers are included to ensure that the scenario modelled remains credible, noting that in their absence, electricity shortages would occur at frequencies and for periods that would be socially untenable. Green peakers are intended to represent plant that produces electricity in short bursts to balance the market, for example during demand spikes or when the wind drops off. Green peakers do not currently exist at the scale and price outlined in the model, and are not identified as being any specific technology, but could conceptually be a generator running on imported ethanol or biodiesel. They are priced in at high rates reflecting high fuel costs, which generally discounts them from playing a baseload role in the market.

129 The concept of green peakers carries a very broad band of uncertainty. The IBC assumes green peakers could provide electricity to the grid at $480/MWh. However, early work to ground-truth this assumption suggests it may be near the bottom-end of price certainty bands, and they could in fact cost closer to $1,000/MWh, especially in the nearer term. Using the lower value creates a more conservative assessment on the value of NZ Battery options in the economic case, compared to the counterfactual.

130 Some scale of green peakers are included in all of our modelled scenarios as being integral to any 100 per cent renewable system, to help provide balance to the market and meet short term peaks when there is a demand spike, or a drop in wind. The scenarios where an NZ Battery option is built, need significantly less green peaker

plant and fuel. A key future challenge for work within my portfolio is to identify and incentivise the adoption of them.

131 The IBC also identifies a scenario where the market retains some fossil-fuelled plant to meet peaking and dry year requirements– referred to as the “do nothing” scenario. In this scenario, the model calculates the most economically efficient generation stack, regardless of whether it is renewable. It also does not account for the slow retirement of existing assets, like Huntly, nor their market using them for roles other than peaking and dry year, so it is therefore not a prediction of the future.

132 A full list of assumptions for the counterfactual scenario, and therefore the scenarios where NZ Battery interventions occur, is attached as Annex E to the IBC.

The NZ Battery Project also considered demand-side dry year options

The market has demand-side levers in operation now

133 The NZ Battery Project has considered whether demand side responses could make a meaningful impact to help solve the dry year problem. Demand response is where typically large industrial consumers reduce or defer their electricity consumption for a period of time, to help balance the electricity market. Demand response is common across the world for short intervals, such as day/night deferral, and with industries where electricity is a significant input to the production of a good or service.

134 New Zealand’s pulp and paper producers are known to reduce their load during periods of high electricity prices. Further, under their current contract, Meridian Energy can call on the New Zealand Aluminium Smelter (NZAS) to reduce its electricity demand by 250GWh over 130 days during a dry year (noting that the dry year problem is 3,000 – 5,000 GWh). This amounts to 80MW, compared to current consumption of around 570 MW.

Demand-side options would be difficult at a scale large enough to meaningfully impact the dry year problem

135 Delivering 3TWh of energy within three to four months in a dry year requires over 1,000MW of generating capacity.

136 NZAS at 570MW is New Zealand’s largest consumer by a significant margin. The next largest is 100MW, and there are fewer than 10 consumers in total that are greater than 10MW. This number is likely to increase as industries electrify. However, if the market is not able to rely on NZAS to significantly reduce its load, achieving dry year security through demand-side measures would require disrupting multiple large customers for months at a time.

137 There are likely to be many future opportunities for industry (new and existing) to provide a demand-side response for short periods to support peak demand. However, there are few customers whose businesses could withstand a large disruption to their operations for months, with little forewarning.

138 NZAS is no different. It has indicated in conversations with the NZ Battery Project team that its existing 80MW contribution reflects a combination of technical and

commercial constraints. While it may be possible to seek extensions to its existing contribution, it is likely that these would amount to incremental increases above what it currently provides and would not reduce the need for other solutions to substantially solve the dry year problem.

139 Hydrogen production is a potential new industry that could materially contribute to dry year security. That demand response potential is captured as part of the Portfolio option. Datacentres are also commonly identified for this role. However, most datacentres will be providing high-value IT services to NZ-based customers and would not be able to disrupt these services for sustained periods. The Lake Parime datacentre that is being developed near the Clyde power station is just 10MW, and its ability to reduce load stems from its engagement in activities such as cryptocurrency mining.

140 Commercial Information [redacted] may, in the right commercial conditions, be able to provide some additional demand response support. However, it is unlikely that those projects will be of the scale and duration required to address the dry year problem, given the impacts that a deep and sustained disruption to operations would have on a business's viability.

141 While there are few opportunities for demand response for dry year support given the magnitude and duration of response required, demand response more generally will be an important part of the future electricity system in any scenario. For example, shifting charging of electric vehicles from peak periods to non-peak periods will be necessary to manage peak demand. The IBC assumes that most electric vehicle charging can be shifted away from peak periods. It also assumes a certain level of residential batteries will be available, and that some demand will be willing to reduce its load during times of high prices – even if these are sustained for long periods.

142 Except where they engage voluntarily, relying on businesses and households to balance the system can involve significant disruption and harm. The modelling places a high cost on being unable to meet demand. At times, the modelled outcome may identify that some amount of shortage is economically efficient, though it can come with significant social impacts.

A Gateway panel of experts has reviewed the IBC

143 In October 2022, a Gateway review has also been completed by independent experts, overall assessing the project as amber on the 5-point Gateway scale. The panel recommended improvements relating to project hygiene, covering:

143.1 project governance

143.2 iwi engagement

143.3 stakeholder and market engagement

143.4 resourcing

143.5 clarifying the modelling methodology and assurance process for estimating cost and risk.

144 The IBC has been revised to address these issues. The panel also considered it was important to further narrow the options to be considered before work on the detailed business case is instigated. I agree with this approach and my recommendations in this paper reflect it. Progressing work on the NZ Battery Project will necessitate an iwi engagement plan, to bring more structure for the NZ Battery Project's engagement with mana whenua.

145 The panel also considered that, given the cost of the Lake Onslow option is higher than that estimated before the instigation of the project, the project team should reassess the other technologies that have previously been ruled out. The project team is re-running preliminary feasibility assessments over the range of other technologies and report their confidence that other technologies can be ruled out as not meeting the criteria set by Cabinet in the December 2020 Cabinet paper and the investment objectives directing the IBC. While the project team has assessed emerging technologies, I will remain open to feedback and suggestion from the sector for solving the dry year problem with renewable energy.

146 I am satisfied that the IBC and Gateway outcome demonstrate that a robust process has been followed and that no issues have been identified that would materially impact a decision to take the investigation of the Lake Onslow option to Phase 2a, and to continue further work in 2023 on the Portfolio option, and pumped hydro at Upper Moawhango to provide more certainty on their merits and challenges.

Governance

147 Governance of the project to date has been led within MBIE. For the next stages of the project, the governance settings will need to be enhanced to match the significance and complexity of the work, including sustained cross-government engagement. I intend to ensure a structure is in place that ensures appropriate oversight and involvement by a wider range of perspectives and experience. This will need to include input by iwi/Māori. My officials will be guided by Te Arawhiti on how to best achieve ongoing meaningful partnership through the project.

Financial Implications

148 Funding of $100.008 million was provided for the project in 2020/21. MBIE has tagged approximately $30 million for the initial feasibility study (Phase 1). To date, MBIE has spent $19 million on the feasibility work, with $11 million remaining for Phase 1. Commercial Information [redacted] These figures reflect the nature of work in next steps; Phase 2a of the Lake Onslow option involves detailed engineering, environmental and geotechnical assessments, whereas next steps on the Portfolio and Upper Moawhango options requires policy work, strategic alignment and economic modelling.

149 If, subsequent to that report back, Cabinet wishes to undertake more substantial investigation of either or both those options, it is intended that the timetable for and scope of the Lake Onslow work would be adjusted to ensure work can be carried out within the existing appropriation until mid-late-2024. Changes to the Lake Onslow work schedule would have implications for the time and cost of work to a final investment decision and therefore potentially commissioning.

150 Negotiations [redacted]

Legislative Implications

151 Preliminary work indicates that a pumped hydro scheme at Lake Onslow will not be able to be consented under the existing Resource Management Act 1991 or proposed new resource management legislation. Enabling legislation would therefore be needed to provide for consent of the scheme.

152 A final investment decision on the scheme is unlikely to be made before 2027, however, it would be advisable for such a decision to be made once certainty about relevant authorisations, and so delivery of the project, has been obtained.

Impact Analysis

Regulatory Impact Statement

153 A regulatory impact assessment is not required as no policy implications are proposed at this stage of the project.

Climate Implications of Policy Assessment

154 A Climate Implications of Policy Assessment (CIPA) is not required at this stage of the project. More detailed assessment of the impact on carbon emissions will form part of the Detailed Business Case, should Cabinet agree to proceed.

Population Implications

155 There are no population implications at this stage of the project. A detailed assessment of population implications will form part of the Detailed Business Case, should Cabinet agree to proceed.

Human Rights

156 There are no Human Rights implications at this stage of the project.

Treaty analysis and iwi engagement

157 Throughout Phase 1 of the NZ Battery Project, the Government has had sustained and productive with Ngāi Tahu, and its subsidiary Aukaha in regular update and engagement hui, in the spirit of partnership, on developing understanding of pumped hydro at Lake Onslow. Ngāi Tahu has not declared a position on the project. The Government will continue its engagement throughout future work.

158 The Government has and will continue to engage iwi local to the Upper Moawhango area, on pumped hydro. The Government, in a recent hui with those iwi, agreed not to proceed with detailed economic desktop analysis until agreement from those iwi had been achieved.

Consultation

159 The Treasury, Ministry for the Environment, Department of Conservation, Infrastructure Commission Te Waihanga, Te Arawhiti and the New Zealand Defence Force were consulted on this paper. The Department of Prime Minister and Cabinet has been informed.

160 National security or defence [redacted]

Communications

161 I will make a public announcement detailing Cabinet’s decision. Prior to this announcement, key stakeholders will be informed, including the affected landowners near Lake Onslow and the Clutha River/Mata-Au, mana whenua and relevant government agencies.

Proactive Release

162 I propose to proactively release this Cabinet paper and minutes within 30 business days, subject to redaction as appropriate consistent with the Official Information Act 1982.

Recommendations

The Minister of Energy and Resources recommends that the Committee:

1 **note** that in the absence of fossil fuelled-thermal plant, New Zealand needs an alternative form of large-scale dispatchable renewable energy to meet demand when the market is under stress from lower-than-average hydrological inflows

2 **note** that on 16 December 2020, the Cabinet Business Committee, having been authorised by Cabinet to have Power to Act, set up the NZ Battery Project to assess renewable storage options to address the dry year problem, and agreed the NZ Battery

Project should examine the viability of pumped hydro, particularly at Lake Onslow, and consider this solution against alternative technologies [CBC-20-MIN-0090 refers],

3 **note** that the Cabinet Business Committee agreed that the assessment criteria for the NZ Battery project are:

3.1 Objective – To manage or mitigate dry year risk in the electricity system

3.2 Criteria – Any proposal or group of proposals will be assessed against its ability to:

3.2.1 provide at least [5,000 GWh] of energy storage or equivalent energy supply flexibility;

3.2.2 provide significant levels of employment for post COVID-19 recovery;

3.2.3 reduce emissions either directly or indirectly through facilitating decarbonisation;

3.2.4 maximise renewable electricity in order to provide a pathway to achieve the goal of 100 percent renewable electricity;

3.2.5 lower wholesale electricity prices;

3.2.6 be practical and feasible

3.3 and noted that the assessment of any option will take into account wider social, cultural and environmental factors, as well as those identified in the criteria above

4 **note** that the NZ Battery Project team has run a feasibility assessment for the Lake Onslow option, and an early assessment of 28 alternative options, including other hydro storage options, and alternative renewable energy storage options

5 **note** that an Indicative Business Case has been developed for the NZ Battery Project, has been through a Treasury Gateway review and received an Amber rating

6 **note** that the Indicative Business Case identified two preferred options for solving the dry year problem: the Lake Onslow option and the Portfolio option of alternative technologies

7 **note** that further minor edits may be made to the Indicative Business Case before publishing

8 **note** that the Indicative Business Case observes that a more stable future electricity market will further encourage widespread electrification and support a pathway to achieving our climate goals

The Lake Onslow option

9 **note** that the cost of the Lake Onslow option is currently estimated to be $15.684 billion (P50, escalated), excluding transmission

10 **note** that, following a final investment decision, the estimated build time for the Lake Onslow option is approximately 9 years (P50), before it can start pumping

11 **note** that developing the Lake Onslow option comes with environmental, cultural and social impacts which will need managing

12 **agree** to progress work on the Lake Onslow option to Phase 2a, which will include work and advice on:

12.1 the configuration of the Lake Onslow option, including the size of the storage reservoir; the pumping/generation capacity; the lower intake location; and the size of any lower reservoir

12.2 scope a detailed business case, pending approval to start drafting

12.3 further environmental field studies, including water quality, species distributions, translocation trials, archaeological survey and more detailed mitigation, offsetting and compensation work.

12.4 further community, mana whenua, stakeholder and market engagement

12.5 a preferred entity to deliver the project and confirm the associated governance, roles and responsibilities, and accountabilities

12.6 the preferred funding and finance arrangement for the delivery of the project

12.7 procurement and land acquisition strategies

12.8 detailed geotechnical investigations

12.9 other required activities, which may include early works.

13 **note** officials have advised that a Detailed Business Case could be delivered within 18-24 months, with a final investment decision approximately three years later

14 **note** officials advise that following the detailed planning phase, there will be a procurement and implementation phase, before a final investment decision, subject to a Cabinet decision to proceed

15 **note** that progressing the Lake Onslow option will likely require enabling legislation

16 **note** that given the nature and complexity of Phase 2a, it is not likely that any material updates on the Lake Onslow will be ready before the DBC is completed in 2024.

The Portfolio option

17 **note** that the NZ Battery Project has considered alternative technologies as a comparison to the Lake Onslow option

18 **note** that the NZ Battery Project did not find any alternative technologies that on their own could realistically provide enough energy and capacity to the electricity market to solve the dry year problem

19 **note** that combining those alternative technologies into a portfolio, consisting of interruptible hydrogen electrolysis, biomass storage and combustion, and new geothermal plant used in reserve appears to provide a potential alternative solution to the dry year problem

20 **note** that there are known limitations with each of the components of the Portfolio option and uncertainties that need to be investigated further

21 **agree** to continue work on the Portfolio option in order to better understand its full costs, benefits and impacts and investigate how it would be delivered

Pumped hydro at Upper Moawhango

22 **note** that following a GIS scan of New Zealand's waterways, the NZ Battery Project team identified another possible site for a pumped hydro scheme at Upper Moawhango, at the southern end of the Kaimanawa ranges

23 **note** that early and emerging findings suggest that a pumped hydro scheme at Upper Moawhango could provide a large amount of energy storage and generation capacity

24 **note** that its location in the North Island, close to demand centres and north of the High Voltage Direct Current link, could make it very effective despite its limited size relative to the Lake Onslow option

25 **note** that pumped hydro at Upper Moawhango would face some practical limitations, such as interacting with existing hydro assets, that could reduce its ability to solve the dry year problem

26 **note** that the Minister of Energy and Resources , and Adrian Rurawhe MP met with iwi representatives local to Upper Moawhango in September 2022, presented the idea of a pumped hydro scheme at Upper Moawhango, spoke to the findings in the Stantec report, and agreed to only proceed with further work in partnership

27 **note** that the NZ Battery Project team has not been able to fully assess the economic merits of a pumped hydro scheme at Upper Moawhango, having agreed to pause further work until mana whenua agree to such work occurring

28 **agree** to continue further investigative work on the potential merits of pumped hydro at Upper Moawhango, including further consideration of potential impacts on NZDF operations, subject to partnership with, and agreement from local iwi leaders

Next steps

29 **invite** the Minister of Energy and Resources to report back to Cabinet in July 2023 with more information on the merits, risks and trade-offs of the Portfolio option and the potential Upper Moawhango pumped hydro scheme.

30 **note** that that report back will help align the levels of information and understanding of the different options for solving the dry year problem relative to the Lake Onslow option, which will help inform Ministers' decisions on which option(s) to progress to a detailed business case.

Hon Dr Megan Woods

Minister of Energy and Resources