Memorandum

ARUP

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Copies		Reference number MBIE NZ Battery Other technologies scope development	
From	Patrick Gorr, Julie Moriarty, Shivesh Tyagi, Ryan Koh	File reference	
Subject	Technical memorandum on MBIE's screening of long list approaches for Other Technologies scope in the NZ Battery Project		

Memorandum

Executive Summary

This Technical Memo summarizes the high-level review of the “NZ Battery long-list of approaches evaluation” document shared by MBIE on 23rd August 2021. This Memorandum is a follow-up to the workshop on 30th of August 2021, capturing the discussion around various technologies as well as providing some context to the high-level schedule and flexibility for the proposed RfP.

Arup has reviewed the documents and screening criteria used by MBIE in developing the short-list of approaches (or Options). In Arup’s review of the long list of options, Arup has adopted the “Security of Supply” and “Renewable” criteria used by MBIE.

Security of supply is defined as:

- Potential to scale and provide, at a minimum, 1TWh of supply; and
- Potential to provide 3-6 months of reliable power supply

Renewables is defined as:

- Whether the technology uses a fuel or energy vector that is renewable; and
- The potential of the technology to be net zero in the future

In addition to these 2 criteria, Arup has added a criterion of “Practical”.

Feasibility is defined in 3 dimensions:

- Technology readiness level (TRL) of 8 or 9 by 2030;
- Geographical constraints, subsurface requirements, and transportation requirements; and
- Commercial viability – has the technology been proven to be commercially viable globally or in New Zealand.

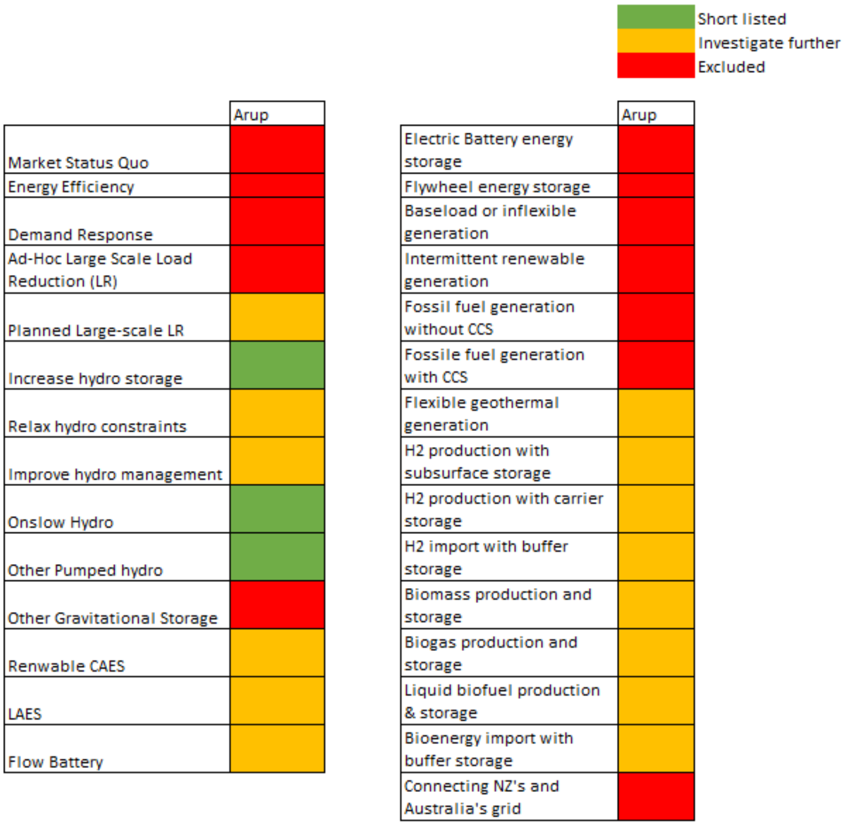
Using these 3 criteria, Arup has conducted a RAG (Red Amber Green) analysis (See Section 1 for further details) on the long list of approaches developed by MBIE. The RAG was assigned as below:

Table 1 RAG approach definition

RAG	Definition
🟩	Technology can meet criterion
🟨	Technology has the potential to meet criterion but has not been proven at required scale or there is some uncertainty associated with the potential of the Technology
🟥	Technology is unable to meet criterion

Based on the criteria Arup opines that in addition to the 4 options in the current shortlist (i.e., Hydrogen, Biomass, geothermal energy storage, and compressed air energy storage), the potential of flow batteries and liquid air energy storage (“LAES”) should also be investigated.

Memorandum



🟩	Short listed
🟨	Investigate further
🟥	Excluded

	Arup
Market Status Quo	🟥
Energy Efficiency	🟥
Demand Response	🟥
Ad-Hoc Large Scale Load Reduction (LR)	🟥
Planned Large-scale LR	🟨
Increase hydro storage	🟩
Relax hydro constraints	🟨
Improve hydro management	🟨
Onslow Hydro	🟩
Other Pumped hydro	🟩
Other Gravitational Storage	🟥
Renwable CAES	🟨
LAES	🟨
Flow Battery	🟨

	Arup
Electric Battery energy storage	🟥
Flywheel energy storage	🟥
Baseload or inflexible generation	🟥
Intermittent renewable generation	🟥
Fossil fuel generation without CCS	🟥
Fossile fuel generation with CCS	🟥
Flexible geothermal generation	🟨
H2 production with subsurface storage	🟨
H2 production with carrier storage	🟨
H2 import with buffer storage	🟨
Biomass production and storage	🟨
Biogas production and storage	🟨
Liquid biofuel production & storage	🟨
Bioenergy import with buffer storage	🟨
Connecting NZ's and Australia's grid	🟥

Figure 1 Comparison of MBIE and Arup's RAG analysis

Arup envisions that the SoW should be broken into 3 Tasks over an 18-week period (See Section 2 for further details). Task 1 will focus on ranking and screening the Shortlist of technology options to develop a Preferred Options list. Task 2 is a feasibility level study based on the Preferred Options list to develop a robust understanding about each technology. Task 3 focuses on ranking the Preferred Options or a combination of Preferred Options based on the feasibility level technical characteristics defined in the previous Task 2.

There is some flexibility around the schedule, but the drivers are identified to be procurement times and number of Preferred Options studied under Task 2 and 3.

Beginning on 18th of October 2021 will result in work completing by the week beginning 7th March 2022 (18 weeks + 2 weeks of allowance for the Christmas season). This allows for 3 weeks of float for the Consultant & MBIE before the end of March 2022.

Technology Characteristics

Table 2 Characteristics of technology options

Technology	**Green Energy Vector**			**Bioenergy**				**Geothermal**	**CAES**	**LAES**	**Flow Battery**
	H$_2$ production with subsurface storage	**H$_2$ production with carrier storage**	**H$_2$ import with buffer storage**	**Biomass production and storage**	**Biogas production and storage**	**Liquid biofuel production and storage**	**Bioenergy import with buffer storage**				
1 TWh	Not yet			Not yet	No	Not yet	Yes	Dependent on aquifer	Not yet	Not yet	Not yet, dependent on tank volume
3-6 Months Output	Yes – e.g. storage in depleted petroleum fields [1]	Yes (carrier consideration)	Yes (frequency of import)	Yes, dependent on the amount of feedstock	No	Yes, dependent on the amount of feedstock	Yes, reliant on supply chain	Dependent on aquifer	Not proven but technically feasible	Not proven but technically feasible	Not yet, dependent on tank volume
Renewable	Yes (Green hydrogen)			Release of CO$_2$, but can reach net-zero carbon emissions				No, CO$_2$ production from sub surface	Yes	Yes	Dependent on the energy source
Land required for 1 TWh(ha)	~18	~10	Dependent on the amount of hydrogen imported and storage plan	~105 (0.96 million tonnes of chip @ 30% moisture)	~22 refined to biomethane and compressed to 200bar	~11 but will fluctuate depending on tank dimensions	Dependent on the amount of bioenergy imported and storage plan	Minimal surface land take, depends on underground aquifer suitability.	500,000 m^3 for 110 MW – storage capacity		~2,800 to 3000
Centralised/Decentralised	Centralised	Decentralised	Centralised	Decentralised (5 to 10 separate power plants)	Decentralised	Decentralised	Decentralised	Centralised/Decentralised (dependent on aquifer)	Decentralised	Decentralised	Centralised/Decentralised
TRL (2021)[2]	6	6	5	9	9	9	9	9	6	6	7
Round trip efficiency	30 – 70 %			25% - 30%	35% to 45%	35% to 45%	25% to 45%	10% to 20%	40 – 65%	25 – 70%	60 – 85%
Surface/Subsurface storage	Subsurface	Surface/Subsurface	Surface/Subsurface	Surface	Surface/Subsurface	Surface/Underground storage tanks	Surface/Subsurface	Subsurface	Surface/Subsurface	Surface	Surface
Maximum Scale (Storage) (2021)	No commercial storage facility as of today			Scaled to wooden pellets/ biomass storage[3]	Scaled to biogas storage	Scaled to biofuel storage	Scaled to frequency import and buffer storage	"The Geysers" – 117 square kilometres of 22 plants, installed capacity of over 1.5 GW	290 MW (Germany)	50MW/500MWh (Chile)	200 MW/ 800 MWh (China – redox flow)

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[1] https://meetingorganizer.copernicus.org/EGU21/EGU21-3496.html

[2] https://www.iea.org/reports/innovation-gaps

[3] https://www.drax.com/sustainable-bioenergy/what-is-a-biomass-wood-pellet/

1 RAG analysis

1.1 Hydrogen

The following options are variations of using green hydrogen generated by renewable energy and storing it in various mediums.

1.1.1 H_2 production with subsurface storage

Description

In this approach, H_2 is produced using hydrogen electrolysers powered by renewable energy. Hydrogen is then stored in gaseous state at ambient temperatures in underground caverns. When required, hydrogen is fed into hydrogen-fuelled generation plants (e.g., gas turbines, fuel cells, hydrogen capable gas fired generators) to produce electricity.

Analysis (RAG)

Arup recommends investigating this technology further. The technology has the potential to provide security of supply, is renewable when employing green hydrogen as a fuel source and can be feasible.

There are several issues to be highlighted as part of this investigation:

- **Security of supply**
    - An assessment would need to be made on expected leakage rates which are dependent on characteristics of the respective subsurface storage facility
    - MBIE has identified Ahuroa as a potential subsurface storage location. This is unlikely to provide 1TWh of storage assuming it is available by 2030, and that there are no further projects developed using that space by 2030
- **Feasible**
    - It is uncertain if technology will be proven at the required scale (1TWh minimum) by 2030.
    - This option is also constrained by location and availability of subsurface storage options, majority of which are currently being used for natural gas extraction and storage. Even if those subsurface storage options can be used, contamination of hydrogen will also be a concern to be studied.
    - This option will likely require a major augmentation of power transmission infrastructure and/or new build of a hydrogen transmission network which adds to the capital requirements. This capital requirement would be irreversible.
    - CAPEX requirement is expected to be very high for hydrogen generation especially considering if electrolyser capacity needs to be built within New Zealand. CAPEX

forecasts for hydrogen technology are expected to fall over time but various forecasts vary widely and the cost of storage will impact CAPEX prices significantly.

1.1.2 H_2 production with carrier storage

Description

Similarly, to H_2 production with subsurface storage, H_2 production with carrier storage refers to producing H_2 using renewable energy but storing H_2 chemically reacting it with a carrier (i.e., Toluene or Ammonia). This is done to densify hydrogen and decrease the volume of the overall substance resulting in a larger volume being stored and allows for it to be stored in smaller cylinders. When required, H_2 along with its carrier undergoes a conversion to obtain H_2. H_2 is then fed into hydrogen-fuelled generation plants (e.g., gas turbines, fuel cells, hydrogen capable gas fired generators) to produce electricity.

Analysis (RAG)

Arup recommends investigating this technology further. The technology has the potential to provide security of supply, is renewable when employing green hydrogen as a fuel source and can be feasible.

There are several issues to be highlighted as part of this investigation:

- **Security of supply**
    - The conversion to other carriers for storage, transport, and subsequent reconversion to hydrogen for power generation adds a layer of complexity as well as allows for additional points of failure. This detracts from this option’s ability of providing reliability and availability as a backup baseload power source.
    - 1 TWh of storage which equates to approximately 60 kt -depending upon the technology and the carrier, is theoretically possible but unprecedented. This would require approximately 78ML of MCH or 88ML of NH3 (depending on storage conditions), as an indication of scale.
- **Feasible**
    - It is uncertain that technology will be proven at the required scale (1TWh minimum) by 2030.
    - Land required for conversion plant and storage would be significant. Looking at over 150 20m diameter storage vessels for liquified hydrogen across NZ, with associated electrolysis, liquefaction, regasification and power generation plant and significant buffer zones. A rough estimate for space would be approximately 40 sites across the NZ grid, each being over 10 hectares.
    - This option will likely require a major augmentation of power transmission infrastructure and/or new build of a hydrogen transmission network which adds to the capital requirements.

1.1.3 H_2 import with buffer storage

Description

In this approach, hydrogen is imported from an overseas supplier into New Zealand. The import of hydrogen can be in the form of liquid hydrogen or hydrogen with a carrier. Liquid hydrogen can be re-gasified or hydrogen in carrier can be extracted to then be fed into hydrogen-fueled generation plants (e.g., gas turbines, fuel cells, hydrogen capable gas fired generators) to produce electricity

Analysis (RAG)

Arup recommends investigating this technology further. The technology has the potential to provide security of supply, is renewable when employing green hydrogen as a fuel source and can be feasible.

There are several issues to be highlighted as part of this investigation:

- **Security of supply**
    - The availability and reliability of this option depends greatly on the form of buffer storage noting that NZ will be exposed to global supply chains for hydrogen
    - If stored in carrier, 1 TWh of storage which equates to approximately 60 kt - depending upon the technology and the carrier, is theoretically possible but unprecedented. Would require over 150 of the largest liquid hydrogen storage vessels ever built, as an indication of scale.
- **Renewable**
    - Depending on future developments in global hydrogen certification schemes, hydrogen traded internationally may not need to have been produced from a real-time 100% renewable energy supply. This makes it difficult to determine whether this option would shift emissions offshore or even meet New Zealand’s 100% renewable’s commitment. Would need Monitoring, Verification and Reporting mechanism for the imported hydrogen
    - It is uncertain if that the supply chain for hydrogen will be 100% renewable.
- **Feasible**
    - It is uncertain that technology will be proven at the required scale (1TWh minimum) by 2030.
    - OPEX for this option will be high as it will include CAPEX recovery of the overseas hydrogen production as well as the cost of delivery by ship
    - Land required for conversion plant and storage would be significant. Looking at over 150 20m diameter storage vessels for liquified hydrogen across NZ, with associated electrolysis, regasification and power generation plant and significant buffer zones. A rough estimate for space would be approximately 40 sites across the NZ grid, each being less than 10 hectares.

  - This option will likely require a major augmentation of power transmission infrastructure and/or new build of a hydrogen transmission network which adds to the capital requirements. This capital requirement would be irreversible.

1.2 Bioenergy

The following option are variations of storing energy in biomass, biofuels, or biogas, and generating electricity by combustion of biomass, biofuels and biogas.

1.2.1 Biomass production and storage

Description

In this option, biomass is produced from renewable source such as wood, plants, or animal material and converted to electricity via thermo-chemical methods (combustion, pyrolysis, and gasification processes).

Analysis (RAG)

Arup recommends investigating this technology further. The technology has the potential to provide security of supply, is renewable when the biomass is generated from a renewable resource and can be feasible.

There are several issues to be highlighted as part of this investigation:

- **Security of supply**
  - 1 TWh of biomass would require approximately 1.2m tonnes of biomass depending on LCV. This is an extremely significant amount and would probably require conversation of existing large thermal generation (I.e. Huntly) or up to 5-10 separate power plants operationally. If stockpiled together, there is a significant fire risk and a diversified supply chain set up would be preferred. It would be recommended to regulate minimum and maximum reserve quantities to safeguard against fire hazards.
- **Renewable**
  - Combustion of biomass will lead to carbon emissions. Therefore, while absolute zero is impossible, net zero can be. Additionally, much of the supply chain is likely to be fossil fuel based (e.g., trucks and machinery). There is a possibility that the supply chain can be electrified but this is unlikely to happen by 2030.
- **Feasible**
  - It is uncertain there will be a source of biomass at the scale (1TWh minimum) by 2030, and if there will be enough land to store and produce the biomass within New Zealand. Import would be an option, the Drax facility in the UK imports wood pellets from America at a scale larger than would be required in New Zealand but carbon release during shipping would have to be considered. Anecdotally, we are aware of some industries in New Zealand choosing to install biomass boilers with partial funding from EECA therefore any supply constraints in the local market would have an effect on these projects and the proponents decarbonisation plans.

1.2.2 Biogas production and storage

Description

Biogas is formed via bio-chemical reactions such as anaerobic digestion or fermentation of biomass (crop residues, food scraps, and manure). The biogas can then be stored in underground reservoirs or in steel containers. They are then combustion to power gas turbines which would then generate electricity. Alternatively, they can also be converted into methanol/hydrogen for fuel cell electricity production.

Analysis (RAG)

Arup recommends investigating this technology further. The technology has the potential to provide security of supply, is renewable when the biogas is generated from a renewable resource and can be feasible.

There are several issues to be highlighted as part of this investigation:

- **Security of supply**
    - Gas storage requirement would be enormous, and its viability is uncertain, however preliminary studies have indicated that depleted petroleum fields such as Ahuroa, Kapuni and Maui may contain reservoirs with efficient seal rocks.[4] On the production side, the continuous digester flow and high enough CV waste that will be required for a production of any reasonable scale will probably be unviable.
- **Renewable**
    - Combustion of biogas will lead to carbon emissions. Therefore, while absolute zero is impossible, net zero can be achieved. Additionally, much of the supply chain is likely to be fossil fuel based (e.g., trucks and machinery). There is a possibility that the supply chain can be electrified but this is unlikely to happen by 2030.
- **Feasible**
    - It is uncertain there will be a source of biogas at the scale (1TWh minimum) by 2030, and if there will be enough land to store and produce the biogas.
    - Size of gas storage tanks required could be prohibitive in cost and space.

1.2.3 Liquid biofuel production and storage

Description

Biomass is converted into liquid biofuel through transesterification, using oily biomass such as oily seeds, waste oils, algae and energy crops into ethanol and biodiesel. These liquid biofuels are then stored in tanks and can be used in steam turbines or in diesel engines.

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[4] https://meetingorganizer.copernicus.org/EGU21/EGU21-3496.html

Analysis (RAG)

Arup recommends investigating this technology further. The technology has the potential to provide security of supply, is renewable when the biofuel is generated from a renewable resource and can be feasible.

There are several issues to be highlighted as part of this investigation:

- **Security of supply**
    - Further investigation into how much available feedstock there is to synthesize the required volume of biofuel is required.
    - Multiple plants will probably be required for the synthesis of biofuel as well as the correct feedstock (e.g., UCO – used cooking oil or energy crops)
- **Renewable**
    - Combustion of biofuels will lead to carbon emissions. Therefore, while absolute zero is impossible, net zero can be achieved. Additionally, much of the supply chain is likely to be fossil fuel based (e.g., trucks and machinery). There is a possibility that the supply chain can be electrified but this is unlikely to happen by 2030.
- **Feasible**
    - Potential synergies if existing diesel generators in New Zealand can run on biodiesel
    - A potential capacity-based subsidy like that employed in the UK should help incentivize investment into this technology but the supply chain if privatized will require revenue certainty. It is unlikely that biofuel manufacture plants will be able to run intermittently to supply biodiesel when required.

1.2.4 Bioenergy import with buffer storage

Description

In this approach the source of bioenergy (biomass, biogas, or liquid biofuels) is imported from an international supplier. The way this bioenergy is sourced would need to be renewably done for it to be labelled a renewable energy source and met New Zealand’s 100% requirement. As there are three types mediums for bioenergy (i.e., biofuel, biogas, and biomass), the method of energy storage, and use in electrical generation follows the approaches highlight in the above sections for biomass, biogas, and biofuels.

A successful model of this method is DRAX in the UK which imports biomass from a variety of international suppliers with majority from North America into the UK for electricity generation.

Analysis (RAG)

Arup recommends investigating this technology further. The technology has the potential to provide security of supply, is renewable when the bioenergy is generated from a renewable resource and consumed in a sustainable fashion. This approach can be feasible as demonstrated by DRAX.

There are several issues to be highlighted as part of this investigation:

- **Security of supply**
    - Reliance on the global market and supply chains in other countries.
- **Renewable**
    - Combustion of biomass, biofuels and biogas will lead to carbon emissions. Therefore, while absolute zero is impossible, net zero can be achieved. Additionally, the much of the supply chain will be beyond New Zealand’s borders and likely to be fossil fuel based (e.g., shipping, trucks, and machinery). There is a possibility that the supply chain can be electrified but this is unlikely to happen by 2030.
- **Feasible**
    - Concerns for respective bioenergy types are found in Sections 1.2.1 to 1.2.3.

1.3 Geothermal

Description

Geothermal utilizes the heat energy stored in the earth to generate electricity which is a familiar technology in New Zealand. Geothermal electricity generation can be either via a open loop system where a working liquid or fluid is injected into hot rock and heat transfer via convection is converted to electricity, or in a closed loop system where heat is transferred via conduction. Geothermal energy storage however, is a newer technology employing solar radiation to heat surface water which is then injected into the earth to create a high temperature geothermal reservoir acceptable for conventional geothermal electricity production

Analysis (RAG)

Arup recommends investigating this technology further. The technology has the potential to provide security of supply, is renewable, and can be feasible.

There are several issues to be highlighted as part of this investigation:

- **Security of supply**
    - The scale and reliability of this technology relies on the suitability of the aquifer.
- **Renewable**
    - While geothermal is considered a renewable resource, it will be important to quantify the potential carbon (or carbon equivalent) emissions to understand its compliance with New Zealand’s carbon commitments.
- **Feasible**
    - Potentially high capex depending on depth of aquifer
    - High risk as yield is usually uncertain until operational phase of the plant

    - High risk on viability due to uncertainty of subsurface conditions until plant operation. Test wells are not normally known to give comprehensive subsurface data and are generally expensive.

1.4 Flow Battery

Description

Flow batteries function as a type of rechargeable electrochemical storage where electrical energy is stored as chemical energy in electrolytes. There are various technologies: redox, hybrid, and membrane-less flow batteries. In a redox flow battery, when charging or discharging, the electrolyte is circulated and undergoes reduction or oxidation to either generate or store electricity.

Analysis (RAG)

Arup recommends investigating this technology further. The technology has the potential to provide security of supply, is renewable, and can be feasible.

MBIE has discounted the technology from the perspective of security of supply and that the size of the tanks and electrolyte required would be unfeasible. The storage technology would also require a lot of space for storage.

Discounting the commerciality of the technology at this stage of evaluation, Arup opines that flow batteries could be a technically feasible solution for NZ Battery. The uncertainty around it lies in the tank and electrolyte volume required to meet the 1TWh storage requirements and 3-6 months of energy supply. The scale of the batteries itself would be dependent on the cell size, number and volume of tanks. However, given its potential around lower operating costs, zero-discharge if tanks are disconnected (for seasonal storage), low environmental impact and synergies with existing power transmission infrastructure, further investigations on this technology should be carried out before screening it out at this stage. Due to low usage, batteries life can probably extend from 25 years to 40 years, reducing the replacement costs. The technology has gained traction in the past few years, and countries like the United States of America, China and smaller countries like Singapore are looking at the integration of flow batteries at large scale to provide backup power. Further assessment of flow batteries in Stage 1 of the study will enable MBIE in choosing/discarding the storage technology.

There are several issues to be highlighted as part of this investigation:

- **Feasible**
    - Number of tanks, volume of tanks and cell size for providing 1TWh of supply over -6 months needs to be further investigated.
    - Technology readiness at scale of 1TWh by 2030 needs to be considered
    - Electrolyte type will need to be further understood and potential environmental impacts around disposal and procurement of the electrolyte will also need to be investigated

1.5 Compressed Air Energy Storage (CAES)

Description

In this approach, air is compressed through a compressor using renewable energy and stored in storage system (usually an artificial or natural subsurface system with natural salt caverns being the preference). When required, the air is expanded and passed through a turbine to generate electricity. There are various variations of this technology such as diabatic, adiabatic, isobaric which aim to improve efficiencies of the system.

Analysis (RAG)

Arup recommends investigating this technology further. The technology has the potential to provide security of supply, is renewable, and can be feasible.

There are several issues to be highlighted as part of this investigation:

- **Security of supply**
    - Competing use of subsurface storage space required with hydrogen.
- **Renewable**
    - Consider contamination of hydrocarbons which would lead to emissions when the utilizing subsurface storage options previously used for oil and gas storage.
- **Feasible**
    - Uncertain if subsurface storage options in New Zealand are suitable to use for storing air.
    - Potential costs and technology risks not well understood for size and scale required. CAPEX and OPEX for diabatic plants that use existing sub surface storage considered competitive with pumped hydro. If geotechnical works are required to create subsurface storage spaces, this might end up ruining the business case. Hydrostor AC-CAES technology uses purpose-built caverns for storage, but the cost associated is uncertain.

1.6 Liquid Air Energy Storage (LAES)

Description

In this approach, electricity from a renewable resource is used to liquefy air and stores the liquid air in a tank. When required, the liquid air is heated into gaseous state and the resulting expansion of air is used to drive a turbine to generate electricity.

Analysis (RAG)

Arup recommends investigating this technology further. The technology has the potential to provide security of supply, is renewable, and can be feasible.

MBIE has discounted the technology on the basis that the storage of this technology would be prohibitively expensive in the long term and potential losses and efficiencies of the system would make it unreliable from a security of supply perspective.

Discounting the commerciality of the technology at this stage of evaluation, Arup opines that LAES could be a technically feasible solution for NZ Battery. The uncertainty around its viability lies in its boil-off losses, efficiencies without a cold recycle or thermal store, overall system efficiencies and synergies to co-locating with relevant industrial plants and infrastructure. Given its potential around providing a more energy dense storage system, geographical flexibility, safety, and synergies with existing supply chains for equipment, further investigations on this technology should be carried out before screening it out at this stage.

There are several issues to be highlighted as part of this investigation:

- **Feasible**
    - Losses from system and efficiencies, different operating modes (e.g., without energy recycle streams, or utilizing boil off gas for some base generation) needs to be quantified to understand its comparison with other short-listed items such as liquid hydrogen.
    - Potential costs and technology risks not well understood for size and scale required and need to be further studied. Commercially available solutions are scaling to provide supply in the GWhs now.

Memorandum

2 Proposed Schedule

Approach:
Arup envisions that the scope of work should be split into 3 Tasks that will reasonably take total length of 18 weeks to complete. Task 1 is ranking and screening exercise of the Shortlist of technology options to develop a Preferred Options list. Task 2 (split into Task 2a and 2b) is a feasibility study of the Preferred Options list, to develop a robust understanding about each technology. Task 3 focuses on ranking the Preferred Options or a combination of Preferred Options based on the feasibility level technical characteristics defined in the previous Task 2.

Flexibility and adjustability
Arup understand the time constraints of MBIE’s Ministerial Update in December’ 2021, and final advice due in May’ 2022. Hence, the final delivery of the study should be delivered by March’2022.

Arup has identified 2 key factors for the timeline:

- The start date of the procurement; and
- The number of screened Preferred Options to be studied in Task 2.

A later start date will push timeframes out by an equivalent number of weeks while the number of Preferred Options for Task 2 can either lengthen or compress the timeframe for Task 2. Arup has based the 12 weeks estimate for Task 2 on a technical feasibility study covering the highlighted items in the Appendix, any addition to those might have an impact on the overall timeline. Additional options will push out timeframes while fewer options have the potential for compressing timeframes.
As an example, based on Arup’s preliminary timeframes, a start week of the 18th of October 2021 will result in work completing by the week beginning 7th March 2022 (18 weeks + 2 weeks of allowance for the Christmas season). This provides roughly 3 weeks of float for the Consultant & MBIE before the end of March 2022.

A preliminary high-level schedule is provided below:

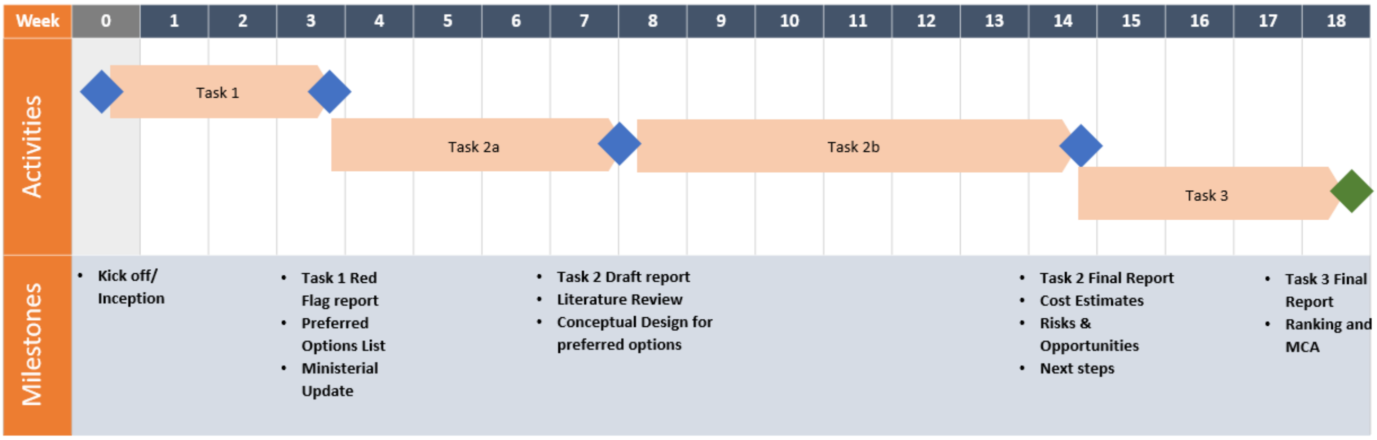

Figure 2 Preliminary high-level Schedule and milestones

Description of Tasks -
Task 1: Pre-liminary feasibility and applicability assessment of technology options
Timeframe: 3 weeks

Description: Desktop study, to analyse the applicability of the storage technology option. Pre-liminary calculations, to support analysis of technologies options against the criteria set out in task 1. The result should be provide a preliminary assessment of the feasibility and applicability of the technology option, enabling MBIE in finalising the technologies to be undertaken in task 2 for detailed assessment as 'preferred technologies options'.

Criteria:

- Security of Supply
- Renewable
- Technical Feasibility

Task 2a & 2b: Feasibility assessment of technology options
Timeframe: 12 weeks (Task 2a: 4 weeks & Task 2b: 8 weeks)

Description: Detailed technical study, to assess the technical feasibility and the plausibility of the preferred options. This will build on the work done in Task 1 with recommendations based on a multidisciplinary assessment across technical, costs, and risks associated with each technology. There will be multiple deliverables from task 2.

Consultant will produce report at the end of each task, report should include the following considerations:

Task 2a

- Literature review
- Conceptual Design

Task 2b

- Cost evaluation
- Risks & Opportunities
- Next steps

A breakdown of the parameters that Task 2 will encompass is attached in A1.

Task 3: Ranking and MCD Analysis

Timeframe: 3 weeks

Description: Ranking of different technologies based on identified parameters. Arup envisions this to be an iterative Multi-criteria decision analysis with the final conclusions to select a single technology or a combination of multiple technology based on MBIE's requirements

3 Feasibility Study parameters

Tasks	Theme	Subtheme	Subject
Task 2A	Literature review	Introduction	Description of technology
			Sub technologies or similar / alternative technologies available
			Status quo of projects with similar technologies present
	Conceptual Design	Approach (Description of design)	Energy source
			Energy transport
			Energy Storage
			Energy generation (into grid from fuel)
		Infrastructure requirements	New build
			Potential use of existing infrastructure
		Geographical requirements	Requirements of entire project (energy production, transport, storage and generation)
			Ranking of potential sites for locating project in NZ
		Scale	Economies of scale and relationship between cost and scale
			Identify optimal/ most efficient scale for Project to be deployed
		Operational flexibility	Ability of Project to vary output (power and energy over time horizons - i.e., 3-6months)
			Hard Constraints (difficult to manage at reasonable cost)
			Soft constraints (can be managed simply)
		Performance parameters	Capacity
			Efficiencies
			Operational ramp up and ramp down
			Time required to synchronise to grid
			Economic lifetime
		Alternative designs	Alternative design options
			Cost benefit/ trade off analysis between options
Task 2B	Costs	Project costs with breakdown into project components	Capex
			Opex
			LCOS
			Carbon emissions

			Decommissioning costs and requirements
			assumptions
			Sensitivity analysis
			Class 3/4? (RFQ requires +/-30%)
	Risks & opportunities (in short, med, med-long, long term analysis)	Technology risk & opportunity	Maturity of Technology (TRL)
			Technology roadmap
			Cost Curve
			Redundancy risk (substitute technologies)/ future opportunities
			Reliability and performance track records
		Market risk & opportunity	Maturity of domestic and international markets for technology and parts
			Competing uses of technology and parts
			Supply chain risk
			Supply and demand forecast
		Technical risk & opportunity	Engineering challenges with EPC & ops
			Safety assurance
			Safety and Hazards
		Environmental risk & opportunity	Life Cycle Assessment including impacts on water and land, biodiversity, carbon emissions
			required consents and permitting status
		Social risk and opportunity	workforce mobilization and demobilization for construction
			operational workforce
			decommissioning phase
			protected land titles, community engagement
		Economic risk and opportunities	Economic impact of project at scale
			Risks and opportunities associated
	Next steps	Feasibility	Key uncertainties
			Further work recommendation
		Implementation Plan	Constructability
			Industry capabilities
			lead time for construction works and anticipated schedule