Milford Opportunities Project

Alternative Energy Supply Options

May 2024

Ref: 310104153

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Department of Conservation

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Revision Schedule

Revision No.	Date	Description	Prepared by	Quality Reviewer	Independent Reviewer	Project Manager Final Approval
A	08/02/2024	Draft	Phelia Klopper	Robin Spittle	Andrew Bird	Phelia Klopper
B	28/03/2024	Final	Phelia Klopper	Robin Spittle	Andrew Bird	Phelia Klopper
C	15/05/2024	Final Revised	Phelia Klopper	Andrew Bird		Phelia Klopper

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1. Introduction

Milford Sound and the corridor roughly from north of the Retford Stream are not connected to the national electricity grid and Knobs Flat and Piopiotahi are currently reliant on micro-grids for their electricity needs. Most electricity is currently supplied by hydropower and diesel generators.

This report investigates the various options to supply low/zero carbon electricity to the region. Hydropower, solar power, wind power, tidal power, wave power, biogas and geothermal energy are discussed.

Renewable energy sources usually provide an intermittent power supply and with the supply not following the demand pattern. Therefore, energy storage is required to capture and store the energy during low demand periods for use during high demand periods. Energy storage options discussed includes hydrogen, water, batteries, flywheels, and compressed air.

Furthermore, extending the national electricity grid is assessed as an alternative solution.

2. Supply options

2.1 Hydropower

The hydropower potential for the Milford Opportunity Project has been assessed in two reports by Stantec and will not be discussed in much detail here. Please refer to the reports "MOP Energy Existing Hydropower Potential" and "MOP Energy Assessment Additional Hydropower Potential".

Table 2-1: Hydropower strength and weaknesses

Strengths	Weaknesses
Established technology – especially in a hydropower rich country like New Zealand.	Potential to have large environmental consequences/ can be hard to consent.
Low operational expenditure.	High capital expenditure.
Longer lifetime than other technologies, circa 100 years.	Reliant on weather (streamflow), although the 'drop off' in power is not as sudden as solar power or wind power as the catchment provides a buffer.
More efficient than other renewable options.	Little opportunity for storage (at Milford) so would need to be combined with an energy storage solution.
Zero carbon solution.	
Good quality power (frequency, inertia, etc.).	

2.1.1 Opportunities for hydropower

The assessment of hydropower potential was focused on three areas:

- Expansion of the existing hydropower plant at Milford Sound
- Expansion of the existing hydropower plant at Knobs Flat
- New hydropower potential in the vicinity of Node 5 and along the Cleddau River

The results are summarised in the table below:

Table 2-2: Hydropower potential in the project area

	Existing generation (kW)	Potential generation (kW)
Milford Hydro	500 kW	1,900 kW[1]
Knobs Flat Hydro	45 kW	120 kW[1]
Node 5	N/A	~160 kW – ~6,900 kW[2]

[1] These values are based on generation at mean flow. Although there are higher generation options available, these potential generation values seem more viable.
[2] There are various locations and configurations available for hydropower generation at these locations. The actual generation will depend on the energy demand which is still to be confirmed. This range represents the option with the lowest potential power output up to the option with the highest potential output.

Cleddau River Options	N/A	~2,400 – ~13,000 kW[3]

2.2 Solar power

Solar power is generated by photovoltaic panels from sunlight. The panels are most commonly installed on existing structures/rooftops (with appropriate orientations), but it can also be installed on the ground (using custom built supports/structures).

Solar power is an established and growing technology in New Zealand, however, as seen in Figure 2-1, Fiordland has some of the lowest solar power potential in the country. The peak daily solar radiation at Mount Belle is shown on Figure 2-2 below. Over two years, the maximum solar radiation was about 1600 W/m^2 in December, lowering to about between 50 and 400 W/m^2 in June. Solar power contribution is assumed to be mostly during the summer, when peak power demand is also expected.

Kevin Thompson from the Milford Road Alliance has experience with solar panels and have come across various challenges as discussed in an email to DOC's Courtney Hart. Due to the mountainous terrain of the potential sites, site selection would need to take shading from mountains into consideration. To have direct sunlight, sites might need to be located at higher locations rather than at road level.

A further challenge with solar in the region is the cold temperature and rain. Methods for thawing, removing, or preventing ice and dealing with moisture should be considered as frost on the panels can cause damage and make them ineffective. Kevin also mentioned that designs need to consider damage caused by keas.

Table 2-3: Solar power strength and weaknesses

Strengths	Weaknesses
Established technology.	High variability throughout year.
Fairly low capital expenditure compared to some other options.	Weather dependent (sunlight and cloud cover).
Zero carbon solution.	Susceptible to damage from Fiordland's cold weather and keas/ birds.
	Challenging site selection due to mountainous terrain.
	Fiordland has some of the lowest solar power potential in New Zealand (refer to Figure 2-1).
	Intermittent supply, therefore needs to be combined with an energy storage solution.

[3] There are various locations and configurations available for hydropower generation at these locations. The actual generation will depend on the energy demand which is still to be confirmed. This range represents the option with the lowest potential power output up to the option with the highest potential output.

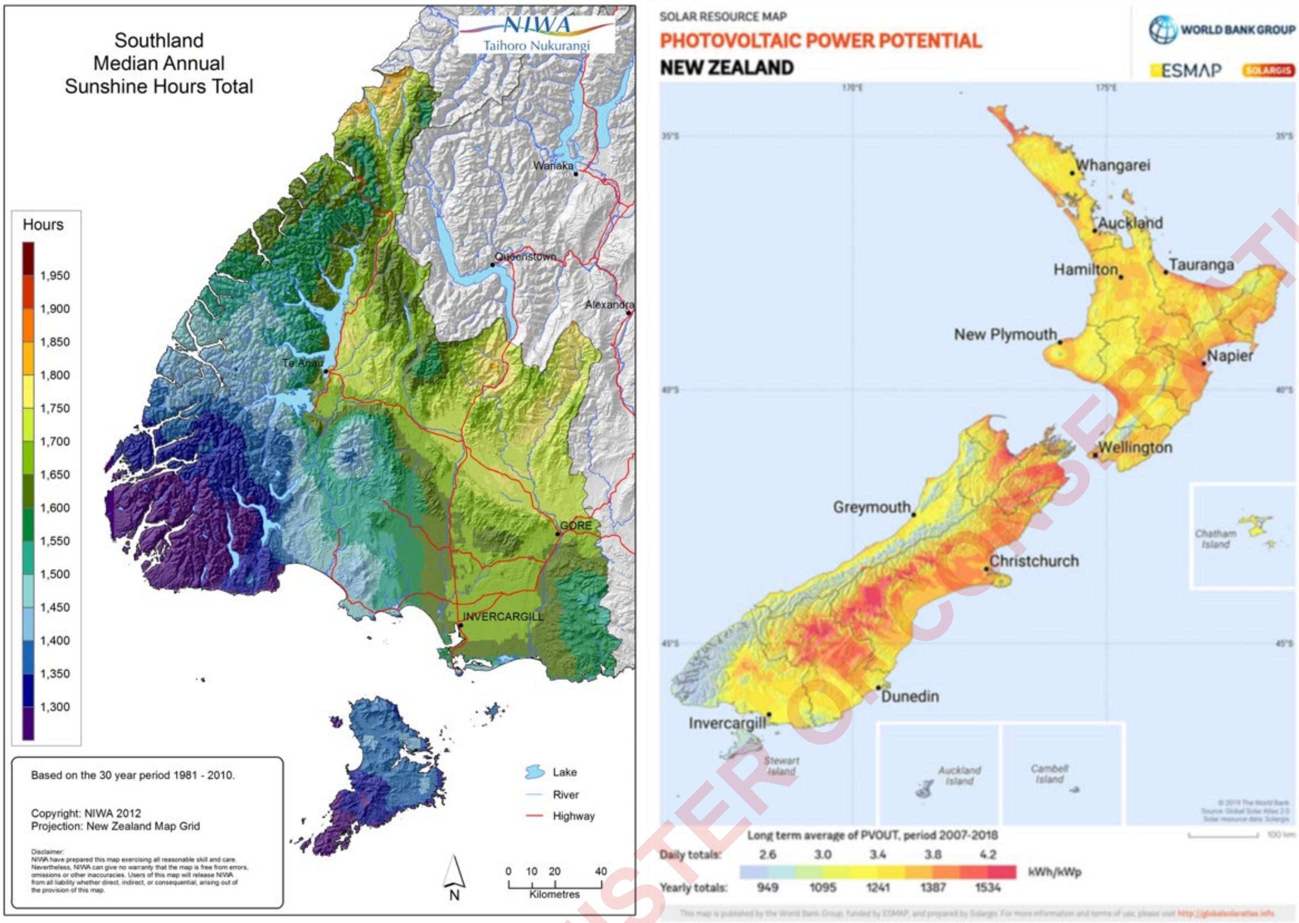

Figure 2-1: Southland sunshine hours (source: NIWA) and New Zealand solar power potential (source: World Bank Group)

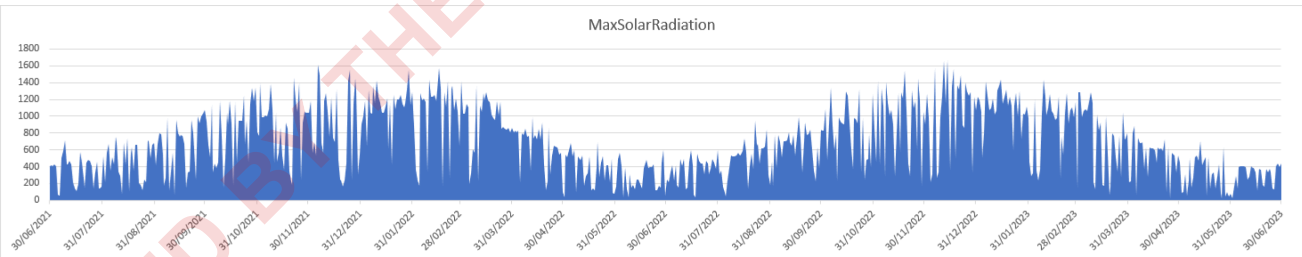

Figure 2-2: Daily Solar Radiation at Mount Belle

2.2.1 Opportunities for solar power

The solar potential at the sites below were assessed by using NIWA's Solarview online tool (Solarview (niwa.co.nz)). It was assumed 18% of the solar energy absorbed by the panels is converted to electricity (this is typical for modern solar panels).

Table 2-4: Daily solar energy potential for each month (kWh/m²/day)

Month	Node 1	Node 2	Node 3	Node 4	Node 5a	Node 5b – Lake Marian	Milford Sound
Jan	0.86	0.86	0.86	0.86	0.84	0.63	0.84
Feb	0.83	0.82	0.83	0.83	0.79	0.53	0.81
Mar	0.68	0.66	0.67	0.68	0.64	0.35	0.67
Apr	0.47	0.44	0.47	0.42	0.44	0.17	0.46
May	0.31	0.29	0.31	0.26	0.30	0.11	0.25
Jun	0.25	0.23	0.26	0.21	0.25	0.09	0.20
Jul	0.33	0.31	0.33	0.26	0.31	0.12	0.26
Aug	0.53	0.50	0.53	0.47	0.49	0.18	0.52
Sep	0.66	0.64	0.65	0.65	0.63	0.34	0.64
Oct	0.78	0.77	0.78	0.78	0.75	0.53	0.76
Nov	0.85	0.84	0.85	0.85	0.84	0.63	0.84
Dec	0.86	0.86	0.86	0.86	0.85	0.67	0.86

In the following stage, the required area of the solar panels can be determined based on the available land and the load demands. We can assume that at most locations the solar panels can be placed on 50% of the existing/planned roofed areas. Using roofed areas for solar installations reduces the capital cost, however, there is the opportunity to install a separate solar array where a suitable site is found and pending environmental approvals. This would increase capital expenditure but could increase the solar output significantly. At Milford Sound, it can be investigated to use the existing airfield to install a solar array. If 50% of this area is used, a solar array of 26,000 m² can be installed. Note that this report only assesses potential resources and quantum. Actual demand will be addressed in the Recommendations Report and sites for installation will be addressed in further project phases.

John McCutcheon of Milford Sound Infrastructure shared that the peak energy demand at Milford Sound is during the shoulder periods due to the heating demand at the fully occupied Mitre Peak Lodge and Southern Discoveries staff quarters during these times. As the solar potential during the shoulder periods are lower, the solar (and energy storage) system installed to meet the shoulder periods' demands is expected to far exceed the demand of the summer season.

The solar output could be further optimised by either tilting the panels in an optimal position or by using single-axis or dual-axis systems which allows the panels to track the sun's movement and adjust their positions accordingly. At the moment, we assumed fixed panels with 45º tilt.

Table 2-5: Estimated roof areas at MOP nodes

Location	Estimated roof area (m^2)	Average monthly potential energy from rooftop solar (kWh/month)
Node 3 Te Huakaue Knobs Flat	700	13,110
Node 4 Otapara Cascade Creek	125	2,250
Node 5a The Divide / Whakatipu Trails Head:	200	3,610
Node 5a The Divide / Whakatipu Trails Head: Lake Marian	200	2,200
Milford Sound	5,000	89,930

2.3 Wind power

Wind power is generated through wind turning wind turbine blades. Wind turbine installations can vary greatly in size, from household systems to large grid connected systems e.g. New Zealand's largest windfarm which will have a capacity of 222 MW. Wind turbines are designed to operate between specific speeds, too low speeds will fail to turn the turbine and speeds exceeding the design limits will force the turbine to stop operation.

Due to Milford Sound's mountainous terrain, it has some of the lowest mean monthly wind speeds in the country (Macara, 2013) as seen in Figure 2-3. The terrain acts as a shelter from the wind and also directs the wind to be mostly in the northwesterly and southeasterly directions.

Table 1. Mean monthly and annual wind speed (km/hr).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Whangarei Aero Aws	12.3	11.7	11.1	9.8	10.0	10.2	11.3	11.3	11.5	13.1	13.4	12.3	11.5
Auckland Aero	17.9	17.0	16.6	15.1	15.6	15.5	15.9	17.4	18.9	20.9	20.5	19.0	17.5
Tauranga Aero Aws	15.1	14.1	13.8	13.0	13.1	13.0	13.5	13.9	15.7	17.1	16.7	15.8	14.4
Hamilton Aws	11.0	10.3	9.8	8.8	9.3	9.7	10.3	10.8	12.1	13.4	12.7	11.9	10.7
Taupo Aws	13.4	12.5	12.5	11.5	12.3	12.6	11.6	12.5	12.8	15.1	15.2	14.3	13.0
Gisborne Aws	13.1	11.7	11.8	11.1	11.5	11.9	11.8	12.1	13.1	14.4	14.3	13.7	12.6
Napier Aero Aws	15.2	14.4	14.2	12.9	13.0	13.0	13.6	13.9	14.8	16.6	16.4	16.0	14.5
New Plymouth Aws	17.8	17.2	18.0	17.0	18.5	19.1	18.8	19.1	19.8	21.3	20.2	18.6	18.8
Palmerston North Aws	16.2	15.6	15.5	12.9	13.7	13.7	13.9	14.2	15.6	17.0	17.8	16.1	15.1
Wellington, Kelburn Aws	21.6	18.9	19.8	18.4	20.0	19.0	19.7	18.9	20.7	22.8	21.8	21.7	20.4
Nelson Aws	14.4	12.6	12.2	10.3	9.1	8.2	7.8	9.4	11.7	14.0	14.9	15.1	11.6
Blenheim Aero Aws	15.1	14.2	14.1	11.6	11.3	11.3	11.2	11.9	14.5	15.6	16.2	16.6	13.7
Greymouth Aero Ews	13.1	11.1	12.2	13.0	13.4	14.3	14.5	12.8	14.0	14.4	13.8	12.8	13.2
Christchurch Aero	17.7	16.9	15.4	13.1	12.3	11.2	11.3	13.2	14.4	16.2	17.0	17.6	14.7
Lake Tekapo Ews	16.2	13.4	12.8	11.5	11.8	11.0	11.7	11.4	14.6	16.3	16.9	14.9	13.5
Alexandra Aws	13.1	11.0	8.1	7.2	7.0	6.3	7.1	6.1	7.7	11.3	11.3	11.9	9.0
Dunedin, Musselburgh Ews	14.9	14.6	13.8	13.2	13.3	13.5	12.1	13.3	14.2	15.3	15.7	15.2	14.1
Milford Sound Aws	8.8	8.2	7.7	7.5	7.9	8.3	8.6	8.1	8.4	9.1	9.0	9.0	8.4
Invercargill Aero	19.2	17.6	17.1	16.2	15.5	14.2	12.5	13.5	17.2	19.6	20.4	18.8	16.8

Figure 2-3: Milford Sound Mean Monthly Wind Speeds compared to other New Zealand locations (Source: G.R. Macara, 2018)

Wind speeds of at least 6-8 m/s are required for small turbines to be economically viable (21.6 km/h – 28.8 km/s) (BRANZ Ltd, 2022). Other sources referenced minimum speeds of 12 km/h (Hydro Québec, 2024). As the wind speeds in the Milford region does not reach these minimum requirements, it is unlikely that wind energy will be a viable option in this region.

Further investigations might find localised areas with higher wind speeds suitable for wind energy generation, however, the visual impact of these turbines is expected to pose a further challenge, especially at Milford Sound.

Table 2-6: Wind power strength and weaknesses

Strengths	Weaknesses
Established technology.	High variability.
Zero carbon solution.	Weather dependent (wind).
	Public opposition to large installations.
	Negative visual impact on natural environment.
	Intermittent supply, therefore needs to be combined with an energy storage solution.

2.4 Tidal power

Tidal energy generation is still a developing technology and not as widespread as established renewables such as hydropower, solar and wind. It would therefore not be recommended as an ideal option for power generation, especially for a microgrid where the energy should be very reliable. Furthermore, due to the sensitivity of the marine environment in Milford Sound, it is likely that it will not be viable from an environmental perspective.

From a technical perspective two methods of tidal generation is available. Energy can be generated from:

- The water level change between low and high tide (tidal barrage/ lagoons)
- The flowing water directly (tidal stream)

The only node where tidal power could be considered is at Milford Sound. To start assessing its technical feasibility, the tidal resource needs to be quantified by collecting velocity data of the currents and data on the tidal patterns. The typical tidal range in Milford Sound is about 1.6 m, with the maximum being about 2.9 m. This tidal range is not considered economically feasible to produce electricity, where the required water level difference is typically about 5 m (Shetty & Priyam, 2022). Velocity data of the currents is unknown and would need to be assessed before commenting on its technical feasibility.

As Milford Sound has many boats of varying sizes, the design and installation of tidal energy turbines should consider not affecting the boats. Assuming a turbine diameter of 10 m, Milford Sound is deep enough to allow for boats to pass overhead (see Figure 2-4).

Tidal power is not considered a viable option for this project due to being a developing technology, not being expected to be technically feasible, and the sensitivity of the marine environment in Milford Sound.

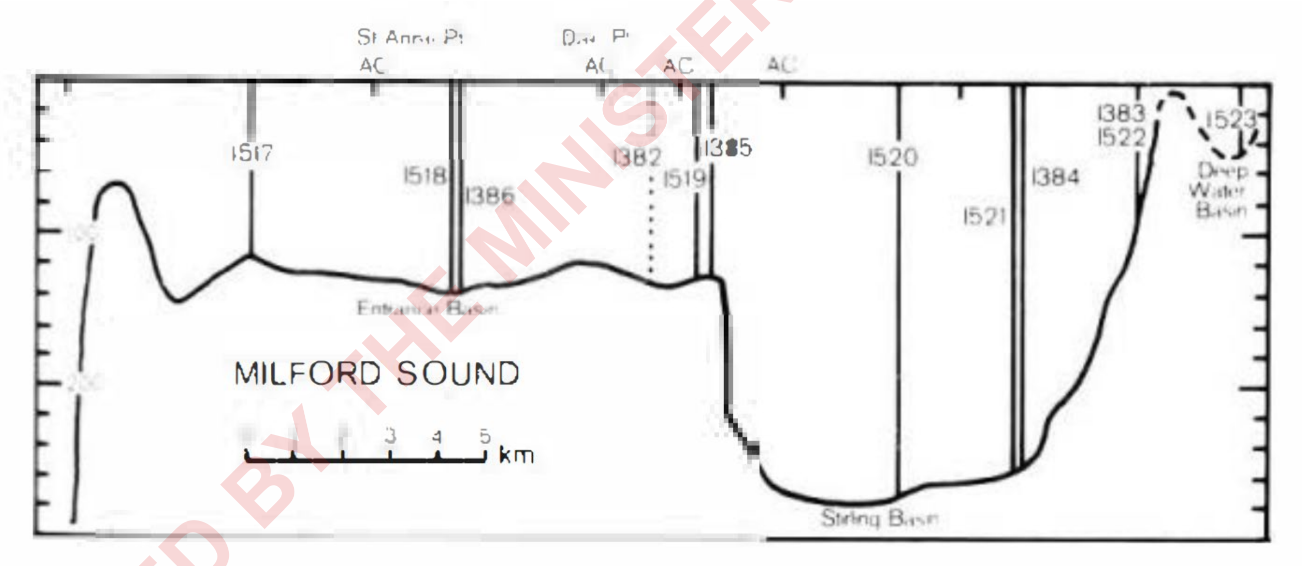

Figure 2-4: Longitudinal section of Milford Sound. Source: (Stanton & Pickard, 1981)

Table 2-7: Tidal power strength and weaknesses

Strengths	Weaknesses
100% renewable energy source with no carbon emissions.	Developing technology, not proven commercially.
Demand node's proximity to the ocean.	Expected to have adverse impact on sensitive marine environment.

2.5 Wave power

Various technologies exist to harness energy from waves, depending on the speed, height, and frequency of the waves. However, most of these technologies are still being tested and not used on commercial basis yet. Apart from not being a proven generation method, it is currently being tested in areas known for large waves, unlike Milford Sound. Furthermore, some of the current wave energy technologies will pose a risk to the protected marine environment of Milford Sound. Wave power is not considered a viable option for this project.

2.6 Biogas

Biogas is produced though anaerobic digestion at wastewater treatment plants. If captured, biogas can produce heat and electricity, and is a renewable energy source. Energy generation from biogas can be assessed at the two locations with wastewater treatment plants, Knobs Flat and Milford Sound.

Biogas can be used for heating or as an alternative to LPG gas as it is mostly methane (CH_4 – around 65-70%) and has a calorific value of about 6 kWh/ m^3 which is the equivalent of around 0.61 L diesel fuel.

Table 2-8: Biogas strength and weaknesses

Strengths	Weaknesses
More reliable than renewables dependent on weather.	Biogas contains impurities even after purification which could limit its uses.
Zero carbon solution.	Biogas can be hazardous due to the methane being highly flammable.
	In colder months there is limited gas production.

2.6.1 Opportunities for biogas

At Milford Sound the staff accommodation is expected to have 300 people. Assuming capturing 20 l biogas per person per day, (Swiss Federal Institute of Aquatic Science and Technology (Eawag), 2024) this equates to a total of 6 m^3 biogas per day. If generating 6 kWh energy from 1 m^3 of biogas, the staff accommodation can produce 36 kWh per day. The hotel can add an additional 6.7 kWh if we assume 1.5 people per room for 50 rooms at 75% capacity.

A total of 42.7 kWh is not considered significant enough to invest in the infrastructure required to capture the biogas and therefore, biogas is not considered a viable option for this project. Furthermore, during the winter, it will be too cold to generate biogas. Day visitors were excluded from these estimates and Knobs Flat was not assessed as it will have even less biogas potential than Milford Sound.

2.7 Geothermal

There are no known geothermal sources in the region and therefore this is not seen as a viable energy source for this project.

2.8 National electricity grid

The existing two-phase line extends about 30 km beyond Te Anau along SH94. It can be considered to extend this line with overland lines or underground cables to nodes along the corridor or all the way to Milford Sound.

This solution will provide reliable electricity from mostly renewable sources (more than 80% of New Zealand's electricity is from renewable sources with plans to increase its contribution). Extending the powerlines could be minimally disruptive to the natural environment if following existing developed road corridors or underground routes.

This option would be able to provide enough clean energy to supply all energy needs of the project without the need of storage systems. Power from the national grid can be used to provide power to the infrastructure needs as well as to charge electric buses and boats.

An unintended downside of connecting to the national grid is that as it is essentially an unlimited power source, it will not incentivise low energy architectural design and conscious power consumption.

Distances to various nodes are shown in the table below (if it is assumed the distribution lines will generally follow the existing roads).

Table 2-9: Approximate transmission line lengths to MOP nodes

Location	Distance to node from end of existing line (km)
Node 3 Te Huakaue Knobs Flat	29
Node 4 Otapara Cascade Creek	41
Node 5 The Divide / Whakatipu Trails Head	53
Milford Sound	82

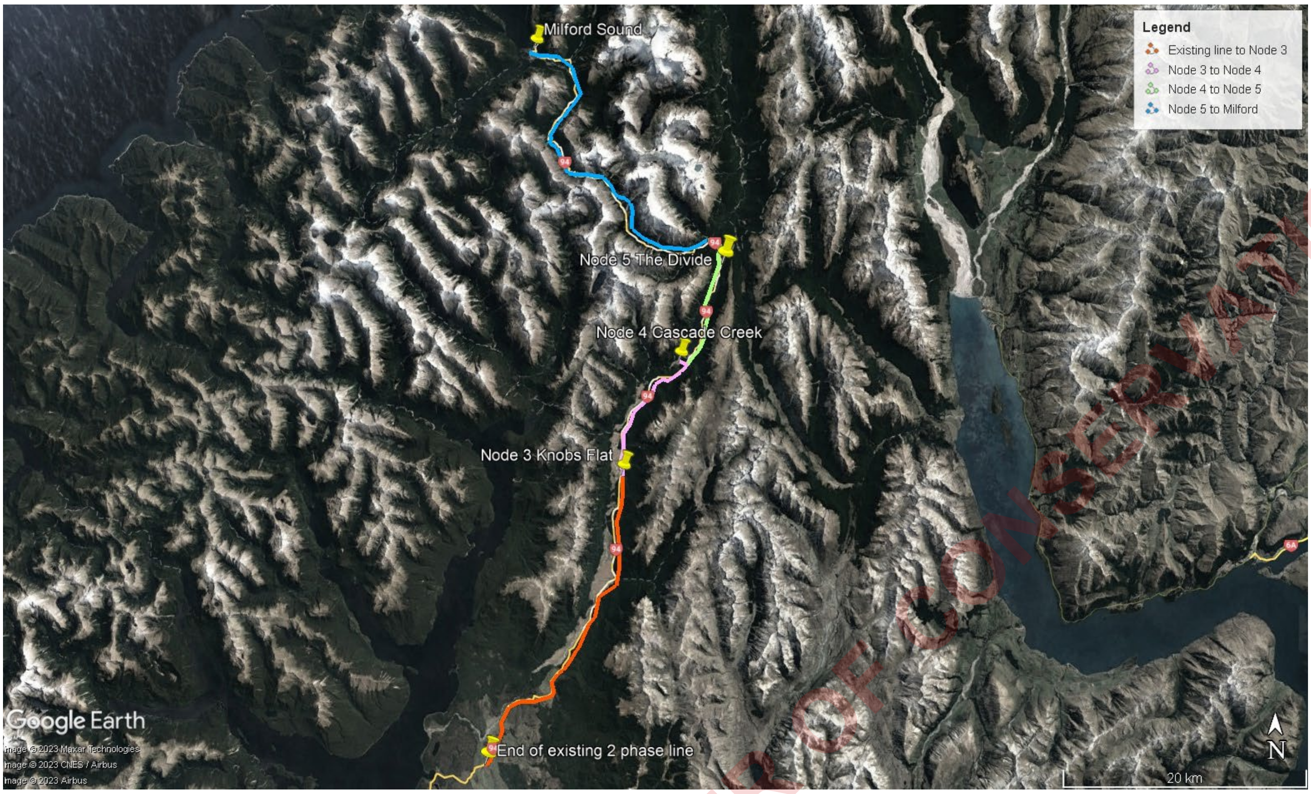

Figure 2-5: Approximate transmission route

Table 2-10: Connection to national electricity grid strength and weaknesses

Strengths	Weaknesses
More reliable than other options.	Capital expenditure expected to be one of the highest of the options.
Low carbon solution, <80% of New Zealand electricity is from renewable energy sources.	Due to “unlimited” supply, low energy design will not be incentivised.
No requirement for batteries or other storage systems.	Technical challenges owing to the capacitance of the cable - surmountable, but with a cost.
Not reliant on weather (except in very extreme situations).	Faults to the buried cable will take time to fix following damage due to events such as avalanches or floods.
Virtually unlimited power supply available for all MOP needs.	
Lower (no) operational costs.	
Smaller environmental impact than other options in terms of infrastructure required.	

3. Storage Options

Due to the variability of renewable energy generation, long duration energy storage will be required for any of the energy supply options, apart from the option of connecting to the national electricity network. In this section, the most common energy storage options are described, and their suitability discussed.

3.1 Hydrogen

Hydrogen can be produced through electrolysis where an electric charge passes through water to split oxygen and hydrogen. The hydrogen is compressed and stored to be used as an energy source and the oxygen released into the atmosphere. If the electricity used in the electrolysis process is from renewable sources, it is referred to as green hydrogen. As a fuel, hydrogen is a clean fuel option with water as its only byproduct, however if not produced using renewable energy, the production can have significant harmful emissions. Furthermore, it requires a large amount of water to produce hydrogen, however, as New Zealand is not a water scarce country water availability is not seen as a limitation for this project.

Hydrogen can be stored for long durations (if space allows) as compressed gas, liquid, or as a solid (where the hydrogen reacts with or is absorbed by a solid).

Various hydrogen projects are currently in operation, under development, or being researched in New Zealand. Including, but not limited to:

- A study by Firstgas, testing the feasibility of distributing hydrogen using their existing gas network.
- Christchurch manufacturing company, Fabrum, who supplies electrolysers and hydrogen storage solutions.
- HW Richardson Group who is planning Hydrogen Refuelling Stations for their trucks as well as other users. The first refuelling station is being planned in Southland.

Table 3-1: Hydrogen strength and weaknesses

Strengths	Weaknesses
Zero carbon solution if using green hydrogen. Low carbon solution if produced using an electrolyser connected to the national grid.	Water use, not an issue except for arid countries. Water can be recaptured in fuel cells.
Hydrogen is versatile, it can be used to produce electricity as well as fuel cells in vehicles.	Hydrogen buses are much more expensive than electric or traditional buses.
Existing gas infrastructure can be repurposed for hydrogen use.	Not an established technology yet.
Suitable for long term energy storage.	Not as efficient as batteries (for vehicles, 20-30% efficient compared to batteries being 70-90% efficient) (Energy Efficiency & Conservation Authority, 2024).
	Transporting and storing hydrogen can have safety concerns and be expensive.
	Current hydrogen production technology is optimised for continuous production/electricity supply. Therefore, it will not be optimal to use "surplus" energy from the intermittent generation sources available if hydrogen storage to be employed within the project area.

3.1.1 Opportunities for hydrogen

The following includes opportunities for hydrogen in the project area:

- Used as electricity supply at Milford Sound (in addition to existing hydropower scheme) and/or other nodes in the corridor in the form of hydrogen powered generators.
- Used as fuel for buses and/or boats.
- Used for space and water heating at Milford Sound and potentially other nodes in the corridor.
- Replace existing gas uses at Milford Sound.

3.1.2 Supply options

3.1.2.1 New production plant

An electrolysis plant to produce hydrogen could be installed at Te Anau using electricity from the national grid, or in the corridor or at Milford Sound with excess power generated from hydropower plants. Only hydrogen produced by excess power from the hydropower plants can be regarded as green hydrogen as the national grid is not 100% renewable.

- Hydropower: The more feasible location for such a plant would be near Node 5 (on the Hollyford River or one of its tributaries). This location has the potential to generate significantly more energy than required by the proposed infrastructure. The location might not be ideal in terms of the logistics of the buses. However, it is closer to Milford Sound than Te Anau, and would reduce the distance to transport the hydrogen (about 30 km compared to 120 km). Installing a distribution pipeline could be investigated at this shorter distance.

  As current hydrogen production technology is optimised for continuous electricity supply, the production from surplus hydropower produced at Node 5 will not be optimal.

- National grid: The option of installing an electrolyser at Te Anau would be simpler in terms of construction, and it would have a more reliable energy input. This could also be more cost effective overall, if assuming hydrogen generators will be used at all nodes and eliminates the need for some other energy generation options along the corridor (e.g. a new hydropower scheme at Node 5 and solar arrays at other locations).

3.1.2.2 External suppliers

As the use of hydrogen becomes more widespread, hydrogen from external suppliers might become more available.

3.1.3 Operational considerations

Bulk hydrogen storage facilities would need to be installed at nodes where hydrogen is required. Due to a safety risk, the storage locations could have conditions regarding the proximity to other infrastructure and could be problematic at locations with spatial constraints.

There are a few options to transport hydrogen to the demand points. It can be transported by road, but this option can pose a safety risk (as would other fuel types), especially when traveling through the Homer tunnel. An alternative, safer transport option is to transport ammonia and to produce hydrogen from the ammonia where the hydrogen is needed. Hydrogen can also be transported through a pipeline.

3.2 Water

Water is the oldest and most efficient way to store energy. The potential energy of the stored water is transformed into mechanical energy and finally into electrical energy in a hydropower plant. The current hydro-electric schemes in the study area are run-of-river schemes, only generating when water is available in the watercourse. This means there are times when no electricity can be generated, whereas stored water will allow for more reliable and flexible generation. However, to store water, water will need to be dammed which can be expensive to construct and prove challenging to gain resource consent.

No opportunities for a pumped-storage system have been investigated.

Depending on the availability of suitable sites, it can be considered to construct a dam as part of the existing hydropower schemes to store water for timely use.

Table 3-2: Water storage strength and weaknesses

Strengths	Weaknesses
Zero carbon solution.	Can be expensive to construct.
Most efficient form of energy storage.	Could have detrimental environmental impacts if not planned and designed correctly.
Can be used with existing hydropower installations.	Could have community opposition.
Proven technology.	Challenging to gain resource consent.
No waste or byproducts.	
Suitable for long term energy storage.	

3.3 Batteries

Lithium-ion batteries are the most used batteries today and commonly used as part of renewable energy systems. Batteries are versatile and flexible. They can be used for small applications such as mobile phones, but also for grid-scale solutions. Furthermore, battery storage has a very fast response time.

Table 3-3: Battery storage strength and weaknesses

Strengths	Weaknesses
Zero carbon solution.	Short lifetime compared to other storage options.
Proven technology.	Environmental impact and cost associated with battery disposal and manufacturing of replacement batteries.
Can be very large scale.	Short term energy storage.
Fast response time.	
Rapidly advancing technology. Costs are expected to fall, as the use and efficiency of batteries are expected to increase in coming years.	

3.3.1 Opportunities for battery storage

Battery storage can be used at all nodes to store energy where renewable generation is taking place.

3.4 Flywheels

Flywheels can be used to store energy in the form of mechanical energy (through the fast rotation of the flywheel). Flywheels are highly efficient and have rapid response times, however, this is used for short-term energy storage and will not be suitable for the requirements of this project.

3.5 Compressed air

Compressed air can be used successfully for large-scale energy storage by compressing air during low demand periods and storing it in large underground caverns. When there is an energy demand, the air is passed through an air turbine to generate electricity. These systems are not as efficient as flywheels and pumped storage systems but can store a large quantity of energy for long durations. They have a much longer life cycle than alternatives such as batteries and no associated chemical waste.

For smaller-scale applications, compressed air can be stored in above-ground tanks. These tanks can be very large and apart from the energy losses when using compressed air, the size of the required storage can be a draw-back.

Heat is generated when the air is compressed. It can be investigated to use this heat for spatial or water heating of buildings.

Table 3-4: Compressed air strengths and weaknesses

Strengths	Weaknesses
Zero carbon solution.	Not as efficient as other storage systems.
Can be very large scale, long-duration storage.	High capital cost.
No waste or byproducts.	Requires suitable site (for underground cavern) or large space for above-ground tanks.
Potential to use as heating source too.	
Long lifetime.	

3.6 Other options

There are other options such as thermal (e.g. molten salt) and gravity energy storage however these technologies are very much in their infancy of development and therefore not considered viable for this project.

3.7 Short term and long term energy storage

The most common solutions for short term and long term storage are described here. Batteries typically provide short duration storage measured in hours or days. Long duration storage (i.e. months or longer) can be provided by hydropower or hydrogen. For hydropower, storage reservoirs are required to hold water until required. Pumped hydro could supplement this depending on availability of renewable energy. Reservoirs are difficult to create especially in a national park environment. Hydrogen is also good for long term storage, but the electrolysers used to produce hydrogen require a steady energy input and is therefore not ideal for use with fluctuating renewable sources. The round trip efficiency of hydrogen is also low.

4. Conclusion

There are a few options to provide low/zero carbon energy as part of the Milford Opportunities Project. Hydropower and solar power are the two most viable generation options from renewable sources and would be recommended to be used together. This solution would need to be supplemented by an energy storage system. Damming water as part of any of the hydropower schemes (if a suitable site is found) would be an efficient way to store energy but will have a high capital cost and could prove challenging to gain resource consent. Battery storage would be the simplest (in terms of procurement, installation, and operations and maintenance) and possibly the most cost effective. However, hydrogen can be explored at higher energy demand nodes.

Connection to the national electricity grid should also be considered as an alternative to a hydropower/solar solution. This option would also be considered a low carbon solution and although the capital cost would be high, this would be the preferred option for reliability, operability, construction/infrastructure footprint, and lifetime costs.

A recommendation can be made once energy demand from infrastructure and transport systems are assessed in conjunction with the options as outlined in this report. To aid decision making, costs for the various energy supply options can be found in the Recommendations Report. A comparison between options and a recommendation will be discussed as part of the Recommendations Report delivered as part of this project.

5. Bibliography

BRANZ Ltd. (2022, September 8). *Wind turbine systems*. Retrieved from www.level.org.nz: https://www.level.org.nz/energy/renewable-electricity-generation/wind-turbine-systems/

Energy Efficiency & Conservation Authority. (2024, 01 18). *Hydrogen energy in New Zealand*. Retrieved from EECA: https://www.eeca.govt.nz/insights/energys-role-in-climate-change/renewable-energy/hydrogen/

Hydro Québec. (2024, January 18). *Wind Power How Does it Work?* Retrieved from Hydro Québec: http://www.hydroquebec.com/learning/eolienne/

Macara, G. (2018). *The Climate and Weather of New Zealand (1st edition).* NIWA.

Macara, G. R. (2013). *The Climate and Weather of Southland (2nd Edition).* NIWA.

Shetty, C., & Priyam, A. (2022). A review on tidal energy technologies. *Materials Today: Proceedings*, 2774-2779.

Stanton, B., & Pickard, G. (1981). Physical Oceanography of the New Zealand Fiords. *New Zealand Oceanographic Institute Memoir 88*.

Swiss Federal Institute of Aquatic Science and Technology (Eawag). (2024, 01 18). *Anaerobic Digestion (Small-scale)*. Retrieved from Sustainable Sanitation and Water Management Toolbox: https://sswm.info/arctic-wash/module-4-technology/further-resources-wastewater-treatment/anaerobic-digestion-%28small-scale%29

Tilley, E., Ulrich, L., Luthi, C., Reymond, P., & Zurbrugg, C. (2014). *Compendium of Sanitation Systems and Technologies. 2ns Revised Edition.* Dübendorf, Switzerland: Swiss Federal Institute of Aquatic Science and Technology (Eawag).

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