HYDROPOWER

A site visit to the
Waitaki Hydropower Scheme

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Introduction

Over the last few years, we have been building up our expertise in the Renewable Energy sector from a sustainability perspective. This may sound strange – what is there to learn you may ask? The primary elements involved in renewable energy are themselves finite, at least in human terms: heat from the sun or the depths of the earth for solar and geothermal energy; wind created by differing atmospheric pressures for turbines; the gravitational pull of the moon for tidal power; and the water cycle for hydro power.

From these natural processes, humans interfere to transfer energy into a format that we use to power our modern world. How humans harness nature's renewable power involves processes that may not themselves be clean or "sustainable": the extraction of minerals for wind turbines; components manufactured for solar panels; building materials such as concrete used to make dams; biodiversity impacts; social effects and consequences.

As one of my favourite bloggers put, *"in order for an energy source to be sustainable, it has to be both renewable and clean, which I'm not sure everyone realises are different things—i.e. A) renewable so it won't run out and B) clean so it won't throw garbage into the atmosphere"*[1].

At Montanaro, when we invest in a renewable energy company, we want to try to understand its full impact – not just of its products and services – but also its operational footprint and its impact on stakeholders. We do this so we can understand the "net" impact of the company. It is no good installing a field of deep-sea wind turbines if the machines need so much maintenance that their consumption of precious metals outweighs the positive production of wind power.

During a series of engagements encompassing renewable companies in the UK, Japan, Greece and the US, we have set out to understand the complexities surrounding these issues. We have met with biomass companies; wind turbine manufacturers; wind field operators; solar power companies; and installers and operators of innovative renewable assets.

Across two weeks in October and November 2022, two members of our Investment Team went to New Zealand and Australia to meet with some of our investee companies. We spent time with Meridian Energy, the New Zealand energy company that operates some of the country's hydro assets. In this note we share what we learned as we spent time in Queenstown and the surrounding area on a tour of the Waitaki Hydro Scheme.

We would like to express our thanks to Meridian Energy and in particular their Head of Investor Relations, Owen Hackston, for arranging such an educational and unique visit.

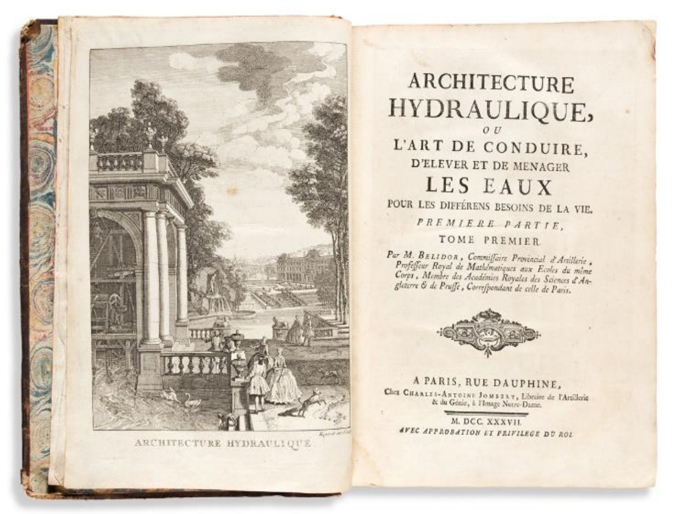
Ed Heaven
Head of Sustainable Investment
December 2022

[1] "The Deal With Solar", *Wait But Why*, T. Urban, 2015, available at: https://waitbutwhy.com/2015/06/the-deal-with-solar.html

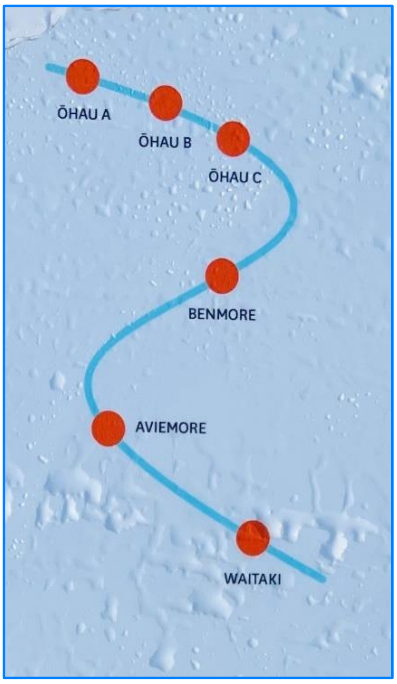
A brief history

Renewable energy has a long history, as my colleague Manroop Bal noted in relation to wind power in her recent site visit report following our trip to Terna Energy in Greece.

Hydropower dates back at least as far as the Greeks and Romans, who developed the first water mills. The earliest physical evidence of a water-driven wheel being used is the "Perachora Wheel" in the Peloponnese during the 3rd Century BC, but written evidence goes back even further. The evolution of the modern hydropower turbine began in the mid-1700s when a French hydraulic and military engineer, Bernard Forest de Bélidor, wrote the ground-breaking *Architecture Hydraulique*, which explores the engineering and mechanics of mills and waterwheels, pumps, harbours and sea power.



New Zealand's history is equally as fascinating and links directly to the Waitaki Hydro Scheme that I visited. In 1904 a Mr P.S. Hay, an employee of the Government's Public Works Department, recognised the electricity generation potential of the Waitaki Valley due to the prevalence of water, the flood plains and the favourable topography that would naturally assist the flow of water along a hydro scheme.

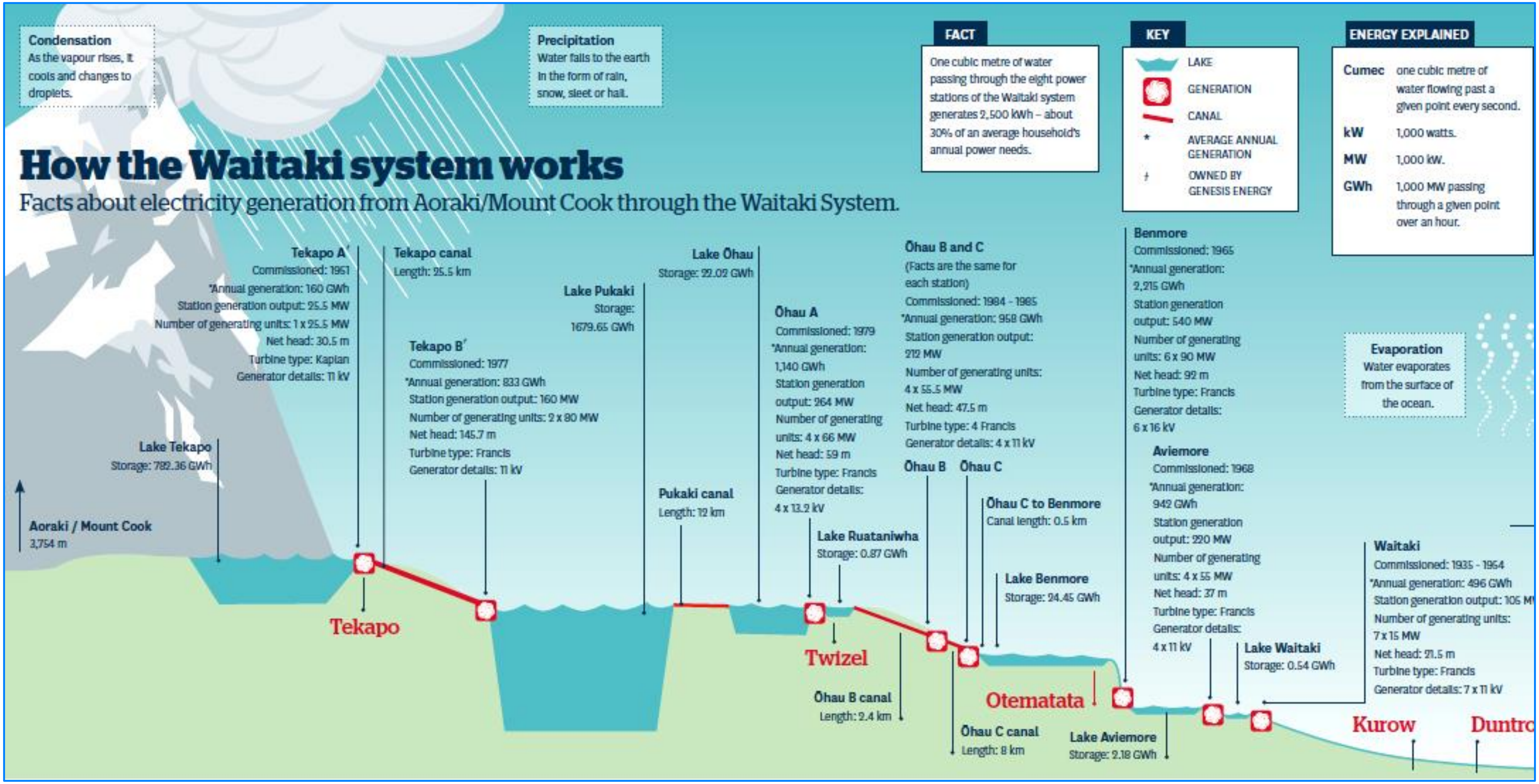


By 1925, the New Zealand needed more electricity to sustain an expanding population and the power stations at Coleridge, Waipori and Monowai were reaching their limits. Hydro engineers charged with finding new dam sites turned their attention to the Waitaki River. Its central location and large flow made it ideal for hydro development and three years later work started on the Waitaki Dam, near Kurow.

The Waitaki hydro scheme consists of eight power stations from Lake Tekapo to Lake Waitaki. Meridian owns and operates six of these stations, generating energy from water flowing from the Southern Alps and across the Mackenzie Basin as it makes its journey out to sea.

The Mackenzie Basin has an interesting history of its own. It was named after a shepherd and outlaw, James Mackenzie, who stole sheep and herded them into what was then a relatively uninhabited area, hoping to claim the land for himself. Although he was caught, the basin is named after him and he is something of a folk hero in New Zealand with tales emphasising his *"superhuman strength, the feats of his fabulous dog, his extraordinary ability as a shepherd, drover and thief, and his rebellious spirit"*[2].

[2] "Biography of James MacKenzie", *Dictionary of New Zealand Biography*, C.Marr, 1990

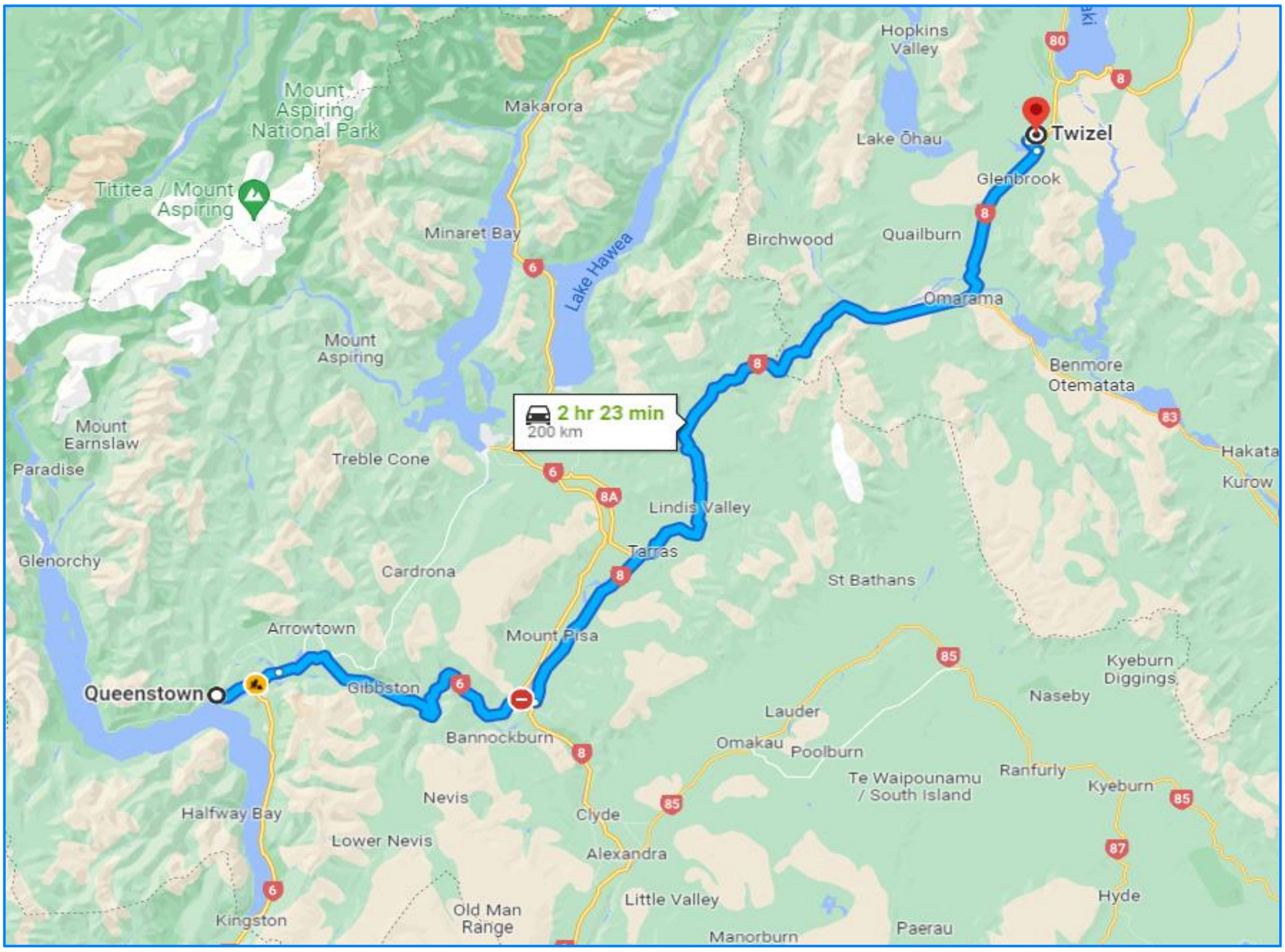

How the Waitaki system works
Facts about electricity generation from Aoraki/Mount Cook through the Waitaki System.
Condensation
As the vapour rises, it cools and changes to droplets.
Precipitation
Water falls to the earth in the form of rain, snow, sleet or hail.
FACT
One cubic metre of water passing through the eight power stations of the Waitaki system generates 2,500 kWh – about 30% of an average household's annual power needs.
KEY
LAKE
GENERATION
CANAL
* AVERAGE ANNUAL GENERATION
† OWNED BY GENESIS ENERGY
ENERGY EXPLAINED
Cumec one cubic metre of water flowing past a given point every second.
kW 1,000 watts.
MW 1,000 kW.
GWh 1,000 MW passing through a given point over an hour.
Tekapo A†
Commissioned: 1951
*Annual generation: 160 GWh
Station generation output: 25.5 MW
Number of generating units: 1 x 25.5 MW
Net head: 30.5 m
Turbine type: Kaplan
Generator details: 11 kV
Tekapo canal
Length: 25.5 km
Lake Pukaki
Storage: 1679.65 GWh
Lake Ōhau
Storage: 22.02 GWh
Tekapo B†
Commissioned: 1977
*Annual generation: 833 GWh
Station generation output: 160 MW
Number of generating units: 2 x 80 MW
Net head: 145.7 m
Turbine type: Francis
Generator details: 11 kV
Ōhau A
Commissioned: 1979
*Annual generation: 1,140 GWh
Station generation output: 264 MW
Number of generating units: 4 x 66 MW
Net head: 59 m
Turbine type: Francis
Generator details: 4 x 13.2 kV
Ōhau B and C
(Facts are the same for each station)
Commissioned: 1984 - 1985
*Annual generation: 958 GWh
Station generation output: 212 MW
Number of generating units: 4 x 55.5 MW
Net head: 47.5 m
Turbine type: 4 Francis
Generator details: 4 x 11 kV
Ōhau B Ōhau C
Benmore
Commissioned: 1965
*Annual generation: 2,215 GWh
Station generation output: 540 MW
Number of generating units: 6 x 90 MW
Net head: 92 m
Turbine type: Francis
Generator details: 6 x 16 kV
Evaporation
Water evaporates from the surface of the ocean.
Aviemore
Commissioned: 1968
*Annual generation: 942 GWh
Station generation output: 220 MW
Number of generating units: 4 x 55 MW
Net head: 37 m
Turbine type: Francis
Generator details: 4 x 11 kV
Lake Tekapo
Storage: 782.36 GWh
Aoraki / Mount Cook
3,754 m
Pukaki canal
Length: 12 km
Lake Ruataniwha
Storage: 0.87 GWh
Ōhau C to Benmore
Canal length: 0.5 km
Lake Benmore
Storage: 24.45 GWh
Waitaki
Commissioned: 1935 - 1954
*Annual generation: 496 GWh
Station generation output: 105 MW
Number of generating units: 7 x 15 MW
Net head: 21.5 m
Turbine type: Francis
Generator details: 7 x 11 kV
Lake Waitaki
Storage: 0.54 GWh
Tekapo
Twizel
Otematata
Kurow
Duntro
Ōhau B canal
Length: 2.4 km
Ōhau C canal
Length: 8 km
Lake Aviemore
Storage: 2.18 GWh

Auckland to Queenstown to Twizel

I began my visit by flying from Auckland to Queenstown, a rush to the airport following a site visit to a healthcare company and then a near two-hour flight.

The views were incredible as we approached Queenstown, passing snow-capped mountains that almost seemed to be within touching distance (I was glad we weren't flying through low cloud). I caught my first glimpse of the famous azure blue rivers that are a feature of this land, a colour caused by glacial flour, tiny particles of rock ground off the mountains by moving ice in the upper reaches of the Southern Alps.

At Queenstown, a small airport where you step off the plane and are through arrivals in a couple of minutes, I was met by Owen from Meridian and we set off on a long drive up through the countryside, with all of its vineyards, shimmering lakes and mountain passes, valleys, peaks and plains, to a small town called Twizel.



A highlight of the drive was stopping at the Linden Pass, the highest pass in the country, and seeing the tussock-covered mountains stretching away into the distance.

The Linden Pass links the Mackenzie Basin with Central Otago and crosses a saddle between the valleys of the Lindis and Ahuriri Rivers, some 971 metres above sea level. Snow covers the mountain tops for most of the year and in the winter can reach all the way down to the road. From where we stopped, the Lindis Conservation Area stretched out, a popular spot for hikers. Despite the blue sky, it was cold!

After close to three hours on the road, we arrived at Twizel, a small town of 1,670 residents[3] whose history is linked directly to New Zealand's hydro scheme. The town was founded in 1968 by the Ministry of Works and Development to house construction workers building the Upper Waitaki Hydroelectric Scheme. It was originally meant to be temporary; the government planned to simply move the houses it had built to other parts of the country where construction workers were needed. But demand existed for a permanent settlement in Twizel, not least for the ongoing maintenance of the nearby hydro assets. Today, Twizel is considered a services and tourist town and Owen explained that Meridian is an important contributor to the local economy, both in terms of direct employment and community support to various initiatives in the town.

[33] As of June 2022

After getting to our hotel, we walked across to a nearby restaurant that was surprisingly full. This was good news given the impact of covid lockdowns on small rural businesses. Many of the people in the restaurant were cyclists, there to ride the trails that run alongside the rivers and canals.

The scenery continued to take my breath away, particularly when we left the restaurant and I looked up at the stars of the Southern Hemisphere. Twizel has little in the way of light pollution.

It was then an early and fresh start to the day, thankfully with a strong coffee in hand. Some pictures of Twizel and Meridian's office are below. Note Meridian's fleet of electric vehicles:

WAITAKI: "WATER OF TEARS"

Our first stop was Lake Pūkaki, a short drive north in the direction of Mount Cook, New Zealand's highest mountain which stands at an impressive 3,724 metres in height. The lake is the largest of three alpine lakes within the Mackenzie Basin, the other two being Lake Tekapo, which feeds into Lake Pūkaki through a 25 km canal, and Lake Ōhau. Water from these lakes forms the Waitaki river, which is known in Maori as the "Water of Tears"; tears shed by Tane, God of the Forest, for Tangaroa, God of the Sea[4]. The river flows for 209 km and enters the Pacific at Glenavy, 100 km north of Dunedin.

Lake Pūkaki is bordered by the Southern Alps, its snow-covered peaks visible in the photo below. It is these mountains that provide the conditions for the lakes. Damp air from the Southern Ocean is blown towards New Zealand by westerly winds and then forced upwards by the Southern Alps where it cools and drops its moisture as rain or snow. The snow or glacial ice can stay locked up for many years, but enough water finds its way into the lakes below.

It is worth pausing to look at this photo. It is a beautiful setting (and for J.R.R. Tolkein fans, was chosen as the location for "Laketown" in *The Hobbit: The Desolation of Smaug*). It shows a vast expanse of water that covers an area of 179 km^2 – but rather than think about it in just H_2O terms, we should think about it in energy terms, for Lake Pūkaki operates like an enormous natural battery. It stores water, ready to be pushed through the Waitaki Hydro-Scheme to generate electricity, as required.

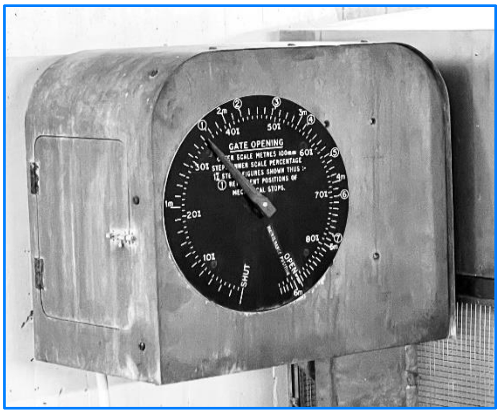
Standing on the shores of the lake, Owen explained that over the years, the lake's water level has been twice raised to increase its storage capacity: by 9 meters in 1952 and by 37 meters in 1976 – effectively doubling its storage capacity – and giving it a current energy storage capacity of 1,595 GWh. Together with Lake Tekapo (770 GWh), Lake Pūkaki provides over half of New Zealand's hydroelectric storage.

Development of the upper catchment area occurred between 1970 and 1985, when water from lakes Tekapo, Pūkaki and Ohau were diverted through a 57 km network of canals to a series of four low-head dams. At the time, *"the upper Waitaki development scheme was the largest of its kind in the world"*[5] and *"nearby Twizel was like a giant ant colony"*[6], with hundreds of workers moving back and forth to the site.

[4] "Waitaki: Waiter of Tears, River of Power", *New Zealand Geographic*, Simon Bloomberg, May-June 2001, available at: https://www.nzgeo.com/stories/waitaki-water-of-tears-river-of-power/
[5] Ibid
[6] Ibid

The lake looked quite high and Owen noted that the water level was 155% above average for this time of year. As the spring melt happens the water level lifts, but a warmer winter had already led to more rainfall than usual. The lake's capacity level was three metres off the top. Lake Pūkaki has an operating range of 13.5 metres. If the water level gets too high, the lake is subject to minimum outflow requirements. The low end of the range is effectively contingent storage. If storage gets low at Lake Pūkaki then national storage is low, meaning less hydropower and a requirement to source energy from fossil fuels.

The lake's original outflow was at its southern end into the Pūkaki River, but this has been dammed and water is funnelled into the Pūkaki Canal through the "Gate 18 Control Gate" down to Lake Ōhau and the first power station under Meridian's control, Ōhau A.



I was taken into Gate 18's control room by Rob Adams from Meridian's Upper Waitaki maintenance team. This nondescript concrete bunker by the side of the road is, Rob noted, probably one of New Zealand's most important utility assets given it acts as the entryway to much of the country's electricity generation. There is on-site control of the gates, although this is typically run centrally from Wellington. I was shown the inner workings of the building and its three water gates, each of which was 33% open. Water charged beneath us into the canal.

Every so often, divers need to be sent down to clean away the build-up of glacial sediment. Given the roar of the water, I asked why a turbine hadn't been installed here and Owen said that it wasn't economically attractive when set against Meridian's wind farm projects.

We then walked outside and down a flight of steep concrete steps to the canal entrance. The volume of water was pretty awe inspiring and here it is at the start of its 12 km journey to Lake Ōhau:

Owen and I then drove along the canal to Ōhau A power station, which was constructed between 1971 and 1979. It has four 66 megawatt generating units and a generation output of up to 264 megawatts. This means Ōhau A generates enough electricity each year for about 144,000 New Zealand homes.

In the foreground of the picture below you can see the four penstocks – to the layman they look like large pipes – taking water from the canal, forcing it together into a more confined space and rushing it down the hill to spin the four turbines in the power station. Once the water has passed through the station, it continues down the scheme to the next power station and the process is repeated.

Overlooking this site and realising that the natural combination of gravity and water flow is generating electricity for so many homes and businesses – and that the same water will go on to create yet more electricity further down the scheme – was interesting from a renewable and sustainability perspective.

With assets built a few decades ago, it is easy to forget the impacts of construction. During the construction of Ōhau A, approximately two million cubic metres of rock and gravel was excavated from the northern bank of the Ōhau River. That is equivalent to about half a million concrete truck loads. Another half a million cubic metres of rock was removed for the tailrace – the tunnel that channels the water out of the station[7].

Raising the water level in Lake Pūkaki changed the local topography, submerging "Five Pound Note Island" (as the name suggests, the Island once appeared on New Zealand's five-pound note) and led to the relocation of Pūkaki village and hotel[8].

Corresponding impacts on wildlife have been noted over the years, a topic that is of increasing importance to investors (as my colleague Kate Hewitt has noted in our recent Biodiversity report). Open, braided river habitats are critical for birds such as black stilts, wrybill plovers and black-fronted terns, species that are native to New Zealand. As their habitats were flooded by hydro lakes or left to dry by

[7] Meridian Energy, available at: https://www.meridianenergy.co.nz/power-stations/hydro/ohau-a
[8] "Balancing the extremes – a brief history of the Pukaki area", *Journal of New Zealand Grasslands*, 80: 15-18, 2018, S.J. Cameron

the canal system, these animals suffered. Black stilts are regarded by Māori as a "taonga species" – a living treasure. As of April 2021, just 170 adult birds are in existence in the wild, although this is at least an improvement on the 23 birds that were recorded in 1981 when an intensive recovery programme was initiated[9].

Given such environmental impacts, it is little wonder that part of New Zealand's environmental movement traces its lineage back to protests against the first hydro dams. The *"Save Manapouri Campaign"* became a national movement in the 1970s, aimed at preventing the raising of the levels of Lakes Manapouri and Te Anau, part of the Manapouri Power Project in the south of the country.

Indigenous populations were particularly effected. Māori values or "taonga" – an object or natural resource which is highly prized in Māori culture – was overlooked as the river was developed for hydro power.

Some improvements have now been seen due to the Resource Management and Ngai Tahu Settlement Acts in relation to unsatisfactory land sales that took place from the 1840s onwards. Now Ngai Tahu is negotiating with Meridian Energy to resolve the issue of customary Māori fishing rights.

Environmental and social impacts are of course intrinsically linked. The early building of the Waitaki scheme was part of the government's *"Make Work"* project during the Great Depression of the 1930s – an effort to create jobs following the economic crash. Over 1,000 labourers manually built the Waitaki Dam, working in dangerous conditions amid freezing winters and scorching summers. *"The site was also notoriously unsafe, and by the time the project was finished, 11 workers had been killed and 1,864 compensation payments made for injuries… [but] workers knew they were fortunate to have a job and accommodation during the Depression"*[10].

Yet the horror of these working conditions incubated what became the birthplace of ground-breaking social policies that included free healthcare and hospitals. An idealistic young doctor, D.G. McMillan, developed a system providing free medical treatment to workers and their families if they paid a small weekly sum into a common fund. After running his practice near the Waitaki Dam site, he became a member of parliament and played a key role in devising the Social Security Act, a scheme that had similarities to what became known as the *"Waitaki Hydro Medical Association's healthcare system".*

Another social benefit has been the popularity of recreational activities on the lakes and rivers. I was told the "legend" of Max Smith, a Ministry of Works engineer in charge of the Upper Waitaki project, who was affectionately referred to as "God" by his adoring colleagues. Keen to leave a legacy of more than dams and canals behind him, Smith put to use a stubborn and creative streak to construct an Olympic standard rowing course on Lake Ruataniwha, much to the chagrin of his government bosses. The course

[9] Department of Conservation, available at: https://www.doc.govt.nz/nature/native-animals/birds/birds-a-z/black-stilt-kaki/

[10] "Waitaki: Waiter of Tears, River of Power", *New Zealand Geographic*, Simon Bloomberg, May-June 2001, available at: https://www.nzgeo.com/stories/waitaki-water-of-tears-river-of-power/

is still used today to host regattas and the waters of the scheme are used for boating, while the area is also popular with campers. Owen mentioned that come the Christmas holidays, space at the best camp sites is hard to come by.

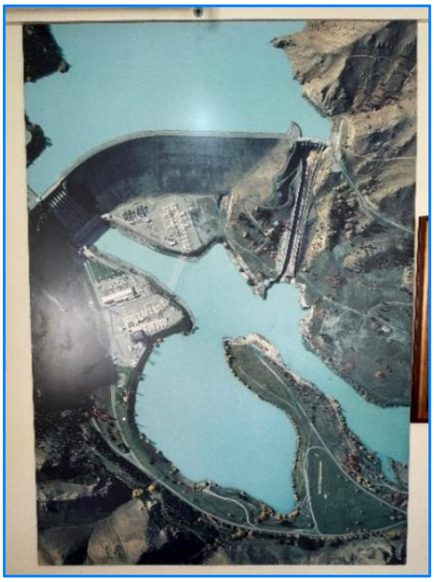
These are just some of the factors that we have to consider when thinking about the sustainability of hydropower. As investors, it can be difficult to balance all of the competing interests to arrive at something that at least the majority of people can agree is sustainable.

Benmore:

From Ōhau A we drove to the end of Benmore Lake to the Benmore Power Station, the second largest hydro station in New Zealand.

Construction on the Benmore dam started in 1958 and the station has a retro feel to it. At the time of construction, it was the largest dam in the Southern Hemisphere. The dam created Benmore Lake, an expanse of water 75 km^2 in size that holds some 1.25 billion cubic meters of water, about 1.5 times the amount of water in Wellington Harbour. At its deepest, the depth of the water reaches 96 meters.

Unlike the concrete based Waitaki dam, Benmore is an earth dam, with a core of low permeability clay material supported by two huge shoulders of river gravel. To give a sense of its scale consider:

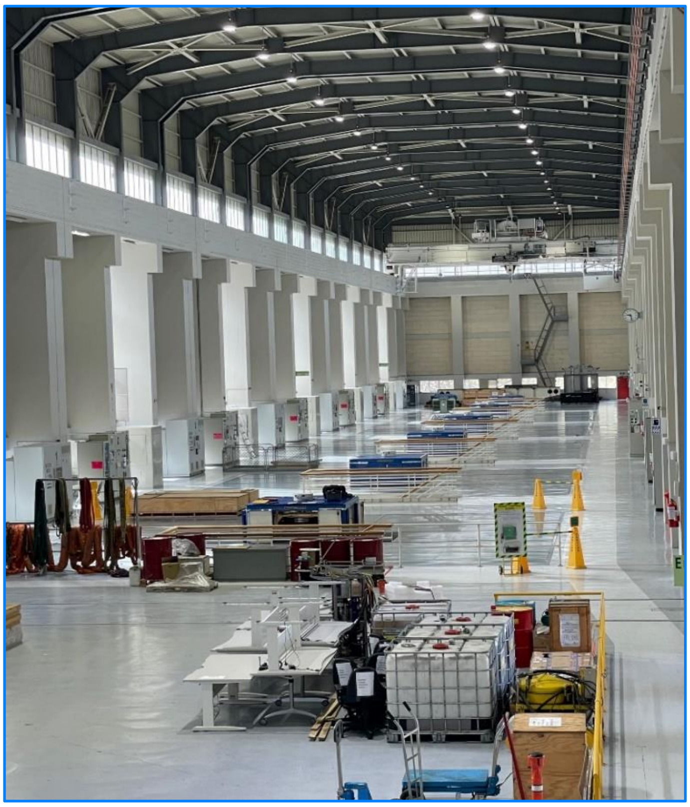


- 28,000,000 tonnes of material used in the dam
- 110 meters high
- 800 metres in length
- 490 meters wide at the base
- 10 meters wide at the crest

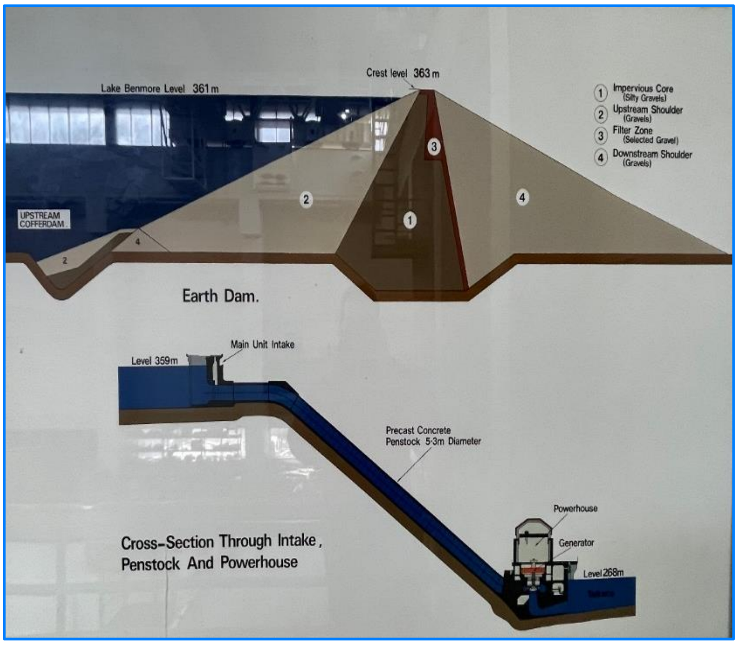
I was taken around the site by Sarah Hutchinson, Meridian's Waitaki Electricity Supply Manager, who was extremely knowledgeable and had a clear affection for what she described as the "*grand old station*".

The staff I met across the site seemed to really enjoy their work. Many have been employed across the hydro scheme for years and Meridian must try to retain the institutional knowledge that has accrued as the workforce ages and retires.

After changing into some flattering overalls, we delved into the heart of the station. We began in the main generator room that looks much like a large warehouse and contains the housing units for the six 90MW generating units, which you can see below in the blue boxes that extend across the floor.



The reason that the ceiling is so high is because each of the rotors weighs some 230 tonnes. Two station cranes that themselves weigh 120 tonnes are needed to lift a rotor for occasional maintenance. As we walked across the floor I saw one rotor head being worked on, although the crane was not needed for this particular operation.



We walked down into the depths of the station where the noise of the generators increased and the corridors were damp with water. Through a door, we saw one of the turbines, spinning away due to the power of nothing more than the velocity of water.

The power produced by Benmore is huge. Each of the six turbines is capable of generating 90MW of power. They spin at 167 rotations-per-minute and are rated at 125,000 horsepower. All hydro stations have something called a *k* factor, the amount of water needed to produce a megawatt. Benmore has a *k* factor or 1.2: so 1.2 cumecs ("cubic meters of water per second") are required to make a megawatt of energy.

A cumec equates to one cubic metre of water, or a thousand litres, flowing past a point in one second. If that has confused you, it is an awful lot of water, moving extremely quickly to create a vast amount of energy. Benmore can power some 298,000 home each year.

After seeing the innards of the station, we walked outside to Benmore's six penstocks. The first thing that struck me was that these were made of concrete. Prior to Benmore, all of the previously built hydro power stations on the Waikato scheme used conventional steel penstocks. It was explained to me that due to New Zealand's fragile economy in the 1960s, importing large quantities of steel for such a large power station was deemed financially impossible. The cost of welding the steel plates was also a factor in selecting concrete, as was the threat of industrial action by the active Boilermakers Union.

Prestressed concrete was therefore selected, an engineering challenge in itself. The six penstocks were created from 318 precast units, one of which is shown below. Each is 2.4 metres long, 5.3 metres in diameter and weighs 57 tonnes. Their wall thickness is 450mm, requiring a special mortar to join the units together.

Together, the penstocks are 130 meters in length, laid down a rock face with a 35-degree slope. It was quite a sight (note the lethal looking concrete steps up the side). Water flows over the spillway at 50km/h and reaches 120km/h by the time it arrives at the deflector plates at the bottom.

We then drove up and over the dam to Benmore's spillway. Although Benmore is a huge site, the dam blends into the surrounding countryside, its grassy bank extending out away from the power station. You can also see the penstocks that lead down to the power station.

The dam's spillway can cope with over 6,000 cubic metres of water per second, about 20 times the mean river flow. By chance, engineers were testing the spillway gates and we saw water power out and down into the river below:

The spillway comprises four spillway gates and two sluice gates. The runoff down to the river is 450 metres in length with a huge block of concrete – an energy dissipater – at the end of the spillway to reduce the power of the water flow into the river. With that, our visit to Benmore finished and there was just about time for a sprint back to the airport in Twizel for a flight to Melbourne, Australia.

Conclusion:

Visiting Benmore made me think back to the last time I had seen a spinning turbine in action. It was January 2020 and I was visiting the Drax Power Station in Yorkshire with Mark Rogers, Montanaro's Head of Investment. This was part of an investigation into the sustainability merits of biomass energy from wood pellets (*see Montanaro's 2020 report,* "The Biomass Debate").

Although under certain conditions such biomass is classified as a renewable source of energy by governments including the European Union and the UK, we concluded that we could not invest in a pure-play biomass energy business. Watching the hydro powered turbine at Benmore, I cast my mind back to the Drax station and the huge volume of biomass wood shipped over from America's Appalachian forests. As we noted in the biomass report, *"each ship from the US typically holds 62,000 tonnes of biomass pellets. Each train carriage holds 70 tonnes of pellets, so the trains are long. These numbers start to get scary when you consider that each biomass unit at Drax gets through 8,000 tonnes of pellets a day. There are 4 of these biomass units: so every two days they get through a ship's worth of biomass. Or to put it another way: each freight wagon holds just 5 minutes' worth of fuel"*.

How to think about the sustainability credentials of hydropower when set against biomass and other forms of renewable energy, such as solar and wind? The sustainability credentials of any hydro dam must consider related environmental and social impacts. Parts of the Waitaki hydro scheme came with the highest of social costs – the loss of life – from unsafe construction environments in the 1920s and 1930s. Other social costs came in the loss of villages and towns that were flooded to create lakes. Negative environmental impacts are clear too: the removal of habitats; declining animal populations; the carbon intensity of the construction process; the use of raw materials such as steel and concrete.

Social positives exist too, however: the employment the scheme has created; benefits from recreational activities; the restoration of animal habitats and environments. The main environmental positive is clearly the creation of renewable energy.

To weigh the positives and negatives from an investment perspective, one solution is to amortise the negative costs or externalities over the lifetime of the asset. This would allow us to consider if a renewable asset is also "clean" (to return to the problem mentioned in the introduction to this paper) and therefore truly *sustainable*.

With this in mind, I argue the Waitaki Hydro Scheme is not only renewable, but clean and sustainable *over the course of its lifetime*. The asset is natural and there in abundance (water); the infrastructure exists and has a long lifespan (Benmore's penstocks should last 100 years); it creates employment and helps to support rural communities (Twizel); and biodiversity issues are being addressed. Finally, water is reused across several power stations making it far more suited to this geography than solar and wind.

The visit showed me that Meridian's hydro assets offer a clean and sustainable source of renewable power. New Zealand's hydropower is renewable; it won't run out; and it doesn't *"throw garbage into the atmosphere"*. If only every country were so lucky.

Sources:

Waitaki hydro scheme flyover: https://youtu.be/zdntVipY7so

Meridian's power stations: https://www.meridianenergy.co.nz/power-stations/hydro

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