EnergyWatch

The Journal of the Sustainable Energy Forum Inc.

Facilitating the use of energy for economic, environmental, and social sustainability

Published by: - The Sustainable Energy Forum Incorporated, PO Box 11-152, Wellington 6142
Email: -info@sef.org.nz Web: - www.sef.org.nz; and www.energywatch.org.nz

The Sustainable Energy Forum Inc. was registered as a charitable entity under the Charities Act 2005 on 30th June 2008. Its registration number is CC36438.

Issue 84 June 2021
editor: Steve Goldthorpe
ISSN 1173-5449 (print) ISSN 1179-4054 (online)

EDITORIAL

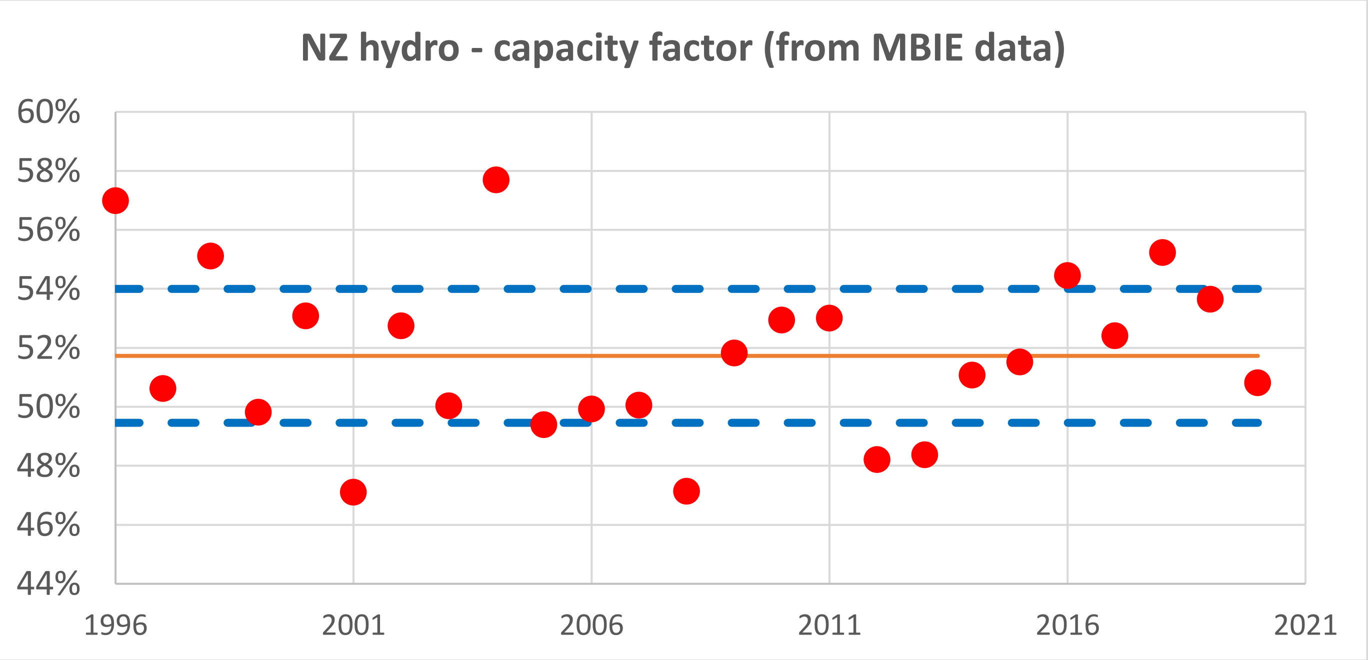
The Dry-year Myth

Conventional wisdom would have it that, because most of New Zealand's electricity supply is hydroelectric, we need a large quantity of stored energy in reserve to be prepared for a year when rainfall is abnormally low. The hydro statistics gathered by the Ministry of Business, Innovation and Employment (MBIE) and presented in the chart below quantify the scale of the dry-year issue that NZ faces. This issue of EW explains why the Lake Onslow scheme is the wrong answer to that problem and would exacerbate it.

Over the last 25 years the hydroelectric generation has averaged 51.7% of the installed capacity. Capacity increased by only 3.8% over that period. There is generally ample hydro capacity to convert above average rainfall into electricity. The average deviation from the mean over this 25-year period is +/- 2.3% of capacity, as shown by the dotted lines on the chart below, which show the normal range of hydro variation.

In 2001, 2008 and 2012-13, hydro generation was below the normal range, but no more than 9% below the average. The extra generation required to bring hydro electricity production up to the normal range was only 1,071 GWh in 2001, 1,091 GWh in 2008 and 1,100 GWh in 2012 and 2013 combined. If supplied by coal at Huntly power station, 1,100 GWh would require two of the 250 MW units operating 24/7 for 3 months on each occasion. That dry-year back-up role would burn about 500,000 tonnes of coal each time, emitting a total of 3.2 million tonnes of CO_2 over 25 years. That quantifies the scale of the dry-year issue.

In the 1992 dry-year hydro production was 46% of capacity, i.e. 11% below average.



This analysis of the dry-year situation suggests that the multi-million dollar "New Zealand Battery" study is using a sledgehammer to crack a nut. That study appears founded on the premise that the Lake Onslow scheme is the only way to future-proof electricity supply in NZ. This issue of EW challenges that premise.

In EW 83 proposals were made to reform the dysfunctional New Zealand electricity industry, which does not provide for funding large-scale non-generating back-up capability. If that issue were fixed by introducing a levy-funded Security of Supply Service (SSS), then it would enable Huntly power station to be repurposed for back-up generation only, potentially using wood-derived fuel with no fossil carbon combustion.

The flagship Lake Onslow project is fatally flawed. Use of daily load-shifting technology of pumped-hydro for year-to-year storage of energy makes no economic sense. Furthermore, an assessment of water losses from an expanded Lake Onslow shows that some of the stored energy is likely to evaporate and leak away before it is needed in a low- rainfall year. Filling the lake would create an electricity shortage.

MBIE's NZ Battery project is proposing to spend $30 million on a feasibility study and a design for pumped hydro using Lake Onslow. I warn that they will find out that it is a fundamentally flawed concept. MBIE should change direction now before more public money is wasted.

There is a role for conventional daily pumped hydro in NZ to accommodate the variability of wind, as discussed in EW81. Such schemes need to be of the right size and location. In particular, the electricity market must be revised to facilitate effective pumped hydro schemes.

In EW82 the hype surrounding the use of hydrogen as an energy carrier was challenged. Another fanciful idea is hydrogen powered planes, as proposed by Airbus. The hydrogen tanks would be just too heavy. Pilots would be looking for somewhere to land to refuel as soon as they had climbed to cruising altitude.

In EW81 the pros and cons of electric vehicles were discussed. EVs are seen as a critical part of achieving New Zealand's CO_2 emission targets by 2050. SEF recently made a submission to the Climate Change Commission showing that the cost of achieving CO_2 emission reduction by switching from petrol-hybrids to fully electric vehicles would cost several hundred dollars per tonne of CO_2 emission avoided. Hence, EVs would not be incentivised by a carbon charge.

Furthermore, the Climate Change Commission was cautioned that treating dual fuel plug-in hybrid (PHEV) cars in the same way as 100% electric vehicles would risk NZ being swamped with older PHEV's with ageing batteries which would become heavy petrol-burning hybrid cars.

The SEF submission to the Climate Change Commission is included here. This issue wraps up as usual with the long-term oil price chart.

I am conscious that I have written most of this issue of EnergyWatch. I would be most grateful for other SEF members to contribute articles.

Steve Goldthorpe, Editor of EnergyWatch

The SEF annual meeting will be held on 23rd June at 5.30 p.m at the Sustainability Trust in Te Aro, Wellington. Some of the issues raised in this issue of EW will be debated.

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A back-up generator for New Zealand

Some years ago, I visited Michael Lawley’s Ecoinnovation setup in Taranaki, which now has four family homes and a successful renewable energy business - all completely off grid. I asked him “What happens when wind, rain and sun resources are meagre, and something breaks down? He replied “*I am not stupid. I have got a Honda generator in the shed*”

That same pragmatic philosophy should be applied on a larger scale to providing Security of Supply Services (SSS) in New Zealand as we aim for a 100% renewable electricity supply.

New Zealand has a back-up generator of the scale required to keep the lights on when the going gets tough. That is Huntly power station. It dates from the time when NZ had a centrally planned electricity system. As noted in the editorial, operating two of the 250 MW units at Huntly flat out for 3 months would provide enough electricity to meet the hydro shortfall in a year when hydro output is below the normal range.

However, there are three problems with Huntly power station: it is old, it is costly to run, and it burns coal, which is a four-letter word these days.

Economics

The structure of the competitive electricity market in New Zealand is such that there is no mechanism for funding the provision of security of supply. It is expected that when the supply from low-cost generators is inadequate to meet the demand, higher cost generators will be used.

On a daily basis that works in NZ. Peak-shaving gas fired generators help accommodate the daily variability of demand, supplemented by the hourly timing of generation from hydro schemes that have flexibility of operation.

As NZ moves towards the ideal of 100% renewable electricity, that daily load-following role can be taken over by carbon-free small pumped-hydro schemes, and maybe also by battery banks, to avoid overbuilding wind and PV capacity. Such schemes would be financed by consuming low-cost surplus electricity at night and generating high value electricity during the day. The price differential needs to be large, to offset the round-trip efficiency loss.

However, that economic model does not work for storing electricity to accommodate year-to-year (or even seasonal) variability, where the price differential between times of plenty and times of scarcity would seldom compensate for the energy loss, even if the round-trip energy efficiency were a high 75%. Also, any payback would only be once per year at best. Funding an “NZ battery” for long-term storage of energy via purchase and sale of electricity would not work economically.

Instead, the electricity market would need to be significantly revised to ascribe a value to Security of Supply Services (SSS) that guarantee the electricity supply while not being used, like Michael’s Honda generator.

That radical change would open a market for SSS, funded by a levy on electricity sales, like an insurance premium. A key condition would be that SSS would only be used when strictly necessary and would not be a player in the general competitive electricity market.

A role for Huntly power station

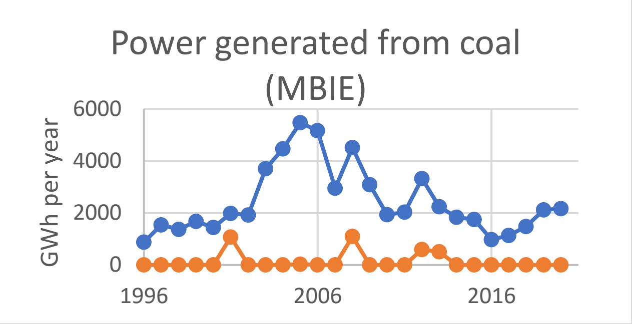
The development of a market for SSS would open-up alternatives to the costly Lake Onslow scheme, which is currently promoted as the only option for addressing the perceived future dry-year problem with the electricity supply system.

Designation of Huntly power station as an SSS facility would require two or three units of that existing asset to be maintained with a secure fuel stockpile. The refurbished power station would need to retain trained staff. The boilers would need to be fired-up occasionally to ensure that the facility was ready to run as required to provide a reliable back-up generation facility for NZ.

Of course, the CO_2 emission question would also need to be addressed. That could be achieved by transitioning Huntly to a wood-derived fuel.

CO_2 emissions from Huntly PS

During the 25 years from 1996 to 2020 coal-fired generation produced 61,000 GWh of electricity from coal as shown by the blue line on the figure below. That coal burn resulted in the emission of 61 million tonnes of CO_2 over those 25 years.



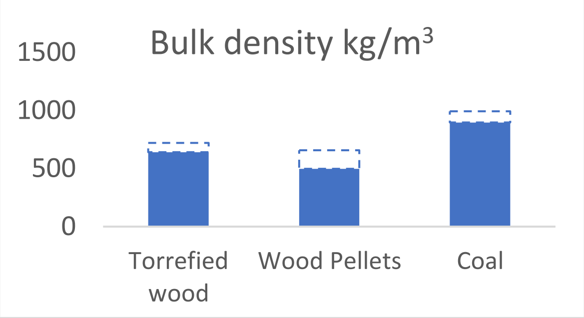
As noted in the editorial, the three low-rainfall years of 2001, 2008 and 2012/13 required in total 3,200 GWh of additional generation to address the "dry-year" issue, as shown by the orange line on the chart above. If Huntly power station had been operated purely in SSS mode for that period it would have been used only three times, i.e., run 24/7 for three months on two 250 MW units to supplement hydro. The consequent CO_2 emissions would have been 95% lower.

The boilers in Huntly power station are multi-fuel; they can burn coal or natural gas. Natural gas has 60% of the CO_2 emissions of coal. Therefore, an alternative fuel source for operation in SSS mode could be natural gas. SSS mode would require a strategic store of 11 PJ of natural gas for each dry-year event and the ability to access that gas at twice the gas extraction rate of the Ahuroa gas storage facility in Taranaki. However, in this SSS scenario, annual leakage of 1.3% of that stored methane would eliminate the greenhouse gas advantage of burning natural gas (or biogas) instead of coal.

Burning wood derived fuel at Huntly

Greenhouse gas emissions from burning fossil fuel in Huntly power station in SSS mode could be eliminated by developing the capability to burn wood-derived fuel in the boilers.

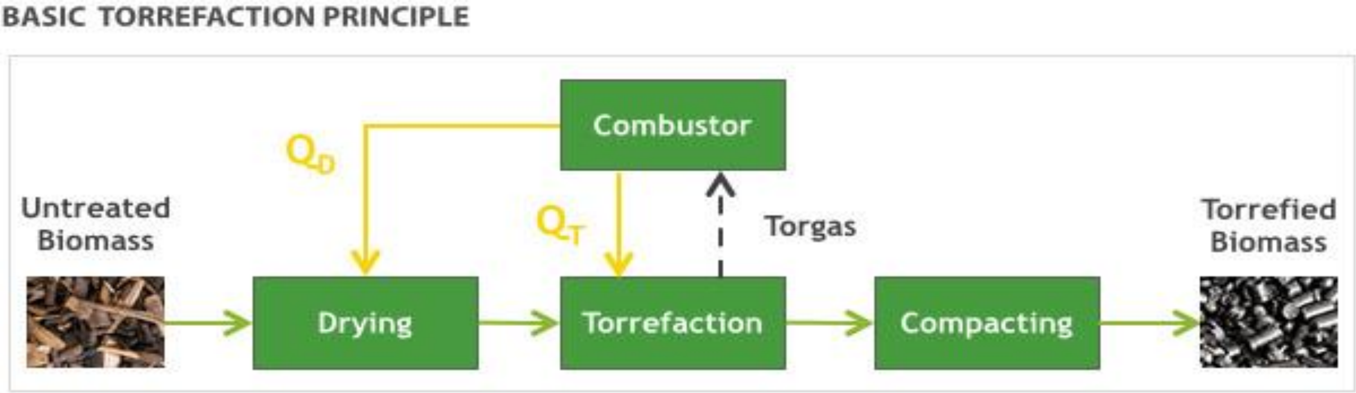
The torrefaction process involves heating wood anaerobically to about 250-300°C to drive off volatiles, which are used as process fuel. The pelletised fuel product has a calorific value of 22.5 GJ/tonne, which is like sub-bituminous coal, but it has a lower bulk density.



An 11 PJ store of torrefied wood fuel would require 20 enclosed silos 25 m diameter and 75 m high to protect it from the weather. Any risk of spontaneous combustion of the stored processed fuel, could be addresses by nitrogen flooding.

The conversion of Huntly power station to SSS mode would require the levy-funded insurance principle of "They also serve who only stand and wait". This use of an existing asset would be much cheaper than ~$4 billion for Lake Onslow.

Steve Goldthorpe



(http://www.blackwood-technology.com/technology/what-is-torrefaction/

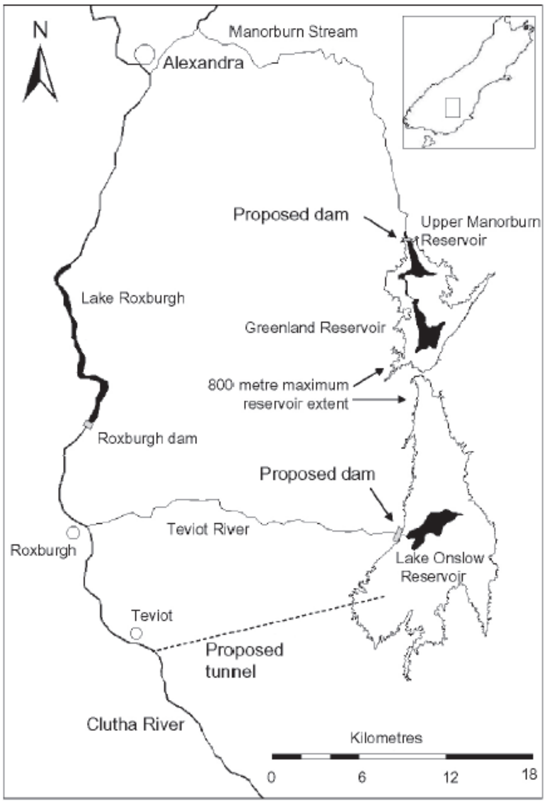
A Critique of the Lake Onslow Concept

By Steve Goldthorpe

A moving target

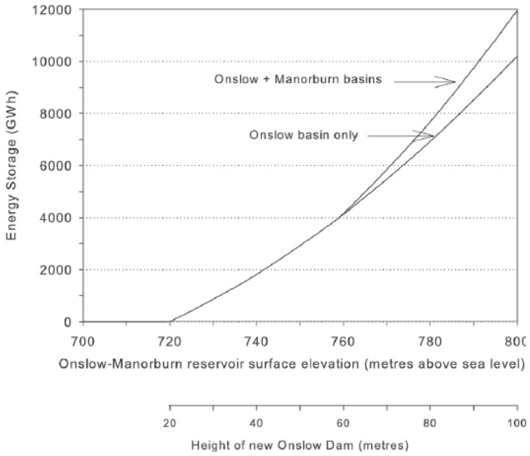
The Lake Onslow concept was first proposed in a short paper to the New Zealand Hydrological Society in 2005 titled "*Note on the pumped storage potential of the Onslow-Manorburn depression, New Zealand*" by W. E. Bardsley Dept. of Earth Sciences, University of Waikato.[1]

Figure 1 - From Bardsley's 2005 note



Prof. Bardsley envisioned an upper hydro lake with an operating range from 720 to 800 metres. connected via a 15-kilometre-long tunnel to the Clutha River near Teviot at 80 metres elevation. Excluding the Manorburn basin extension, he estimated that the stored potential energy would be 10,000 GWh (36 PJ), yielding 8,500 GWh of electricity at 85% turbine efficiency. He suggests a 1,500 MW generator/pump, which could run 24/7 for over 6 months on the stored water.

Figure 2 - From Bardsley's 2005 note



Formation of the raised lake at 800 metres would require a 3 km long dam with an average height of 56 metres across the Teviot River valley[2], which Bardsley proposed would be an earth dam.

The current details of the Lake Onslow project on the MBIE website[3] reduces the scale of the Lake Onslow project to 21 PJ with a 760 metres lake elevation. That scope reduction would reduce the dam to 1.5 km long and 48 m high.

Recent interviews and explanations from Prof. Bardsley[4] indicate some "feature-drift" in response to concerns. To avoid wind-blown dust from the exposure of the lakebed when water is drawn down, he proposes removal from 40 km^2 of moorland of all vegetation and soil down to bedrock schist before the area is flooded.

Bardsley also suggests[5] the release of water into the Taieri river valley that lies to the east of Lake Onslow in order to maintain wetlands there and offset the loss of flooded wetlands. That strategy would increase the water pumping duty.

He suggests the alternative creation of a 24 km tunnel up to Lake Onslow from Lake Roxburgh as the lower pumped-hydro lake. Lake Roxburgh sits at 135 metres, so the hydro head would be reduced by 8% in that case.

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[1] Journal of Hydrology (NZ) 44 (2): 131-135, 2005

[2] Determined with box model. See Page 6.

[3] https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/low-emissions-economy/nz-battery/lake-onslow-option/

[4] https://www.odt.co.nz/regions/central-otago/scientific-thought-behind-hydro-idea

[5] https://www.odt.co.nz/news/dunedin/tunnel-could-mitigate-damage

Peer review of dimensions

I have created box models of the Lake Onslow area using the elevations at spatial coordinates from GoogleEarth at two levels of resolution:-

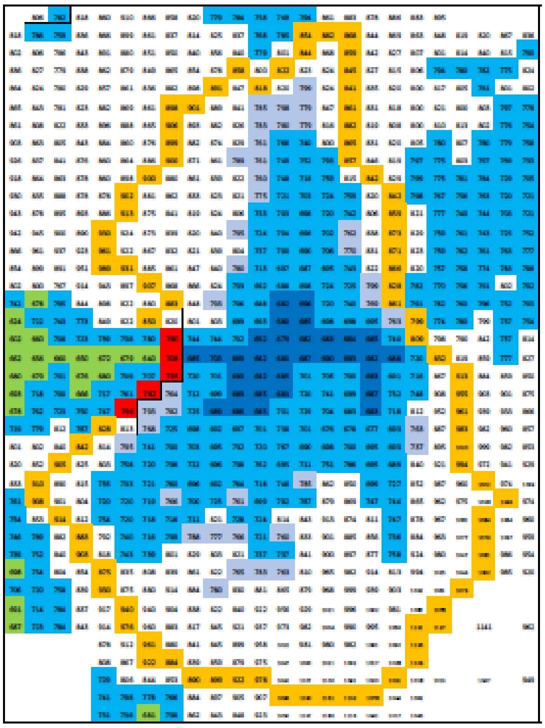
- 30 seconds of latitude (610 m) by 20 seconds of longitude (617 m); and
- 10 seconds of latitude (217 m) by 10 seconds of longitude (310 m)

The elevations reported by GoogleEarth are lakebed elevations not water surface elevations.

I used the higher resolution data to determine the required dimensions of the dams (as noted on Page 5) assuming a dam height 5 m above the high-water level. I have used the lower resolution data to determine the areas and volumes of Lake Onslow in intervals of elevation from 695 m to 800 m and also the perimeter of the water catchment area. The current Lake Onslow water surface elevation level is at 695 m according to the GoogleEarth data. Based on this methodology I have determined the data presented in Table 1, with outlets at 85 m and 135 m.

Figure 3 shows the low-resolution model output. The dark blue region is the current Lake Onslow. The mid blue region is the area that would be flooded to 760 metres. The light blue regions show the additional areas that would be flooded to 800 metres. The black line is the dam that would be required for a Lake Onslow filled to 800 metres. The orange cells indicate the extent of the Lake Onslow rainfall catchment area. This analysis could be reworked at high-resolution.

Figure 3 - Box model of Lake Onslow area



The estimated potential energy store at 35 PJ for the 800-720 metres water store above an 85 m outlet is in good agreement with Bardsley's 2005 figure for maximum storage, excluding the Manorburn extension. Bardsley's 2020 plan of 780-730 m above a 135 m outlet yielding 5TWh is also in fair agreement with Table 1.

However, the estimated potential energy store if the lake is operated in 760 m to 720 m range would only be about 15 PJ, which could generate 3.4 TWh of electricity in a hydro turbine. That is significantly less than the 5 to 7 TWh stated on the MBIE website. Nonetheless, 3.4 TWh of reserve generation would be more than ample for the dry-year risk as noted on Page 1.

Table 1. Approximate assessment of Lake Onslow dimensions (with low resolution model)

	Elevation metres	Area km^2	Lake Volume km^3	Volume km^3 above 720 m elevation	Potential energy PJ above 85 m	Potential energy PJ above 135 m
Catchment Area	-	200	-	-	-	-
Bardsley 2005	800 m	84	6.4	5.4	35.3	32.7
Bardsley 2020	780 m	76	4.8	3.8 (from 730 m)	21.6	20.2
MBIE 2021	760 m	68	3.3	2.3	14.8	13.7
Draw down (2020)	730m	51	1.5	0.5	-	-
Draw down (2005)	720 m	41	1.0	0	-	-
Current lake	695 m	12	0.1	0	-	-

Water balance considerations

The natural water input to Lake Onslow is rainfall. Prof Bardsley notes *"There will also be some unavoidable net water loss to evaporation because of the low 0.6 metre annual rainfall at Onslow"*. NIWA reports[6] *"Central Otago is the driest region of New Zealand, receiving less than 400 mm of rainfall annually"*.

The Lake Onslow catchment area is 200 km^2. So, the natural water input at 500 mm annual rainfall would be 3.2 m^3/s (cumecs), on average.

Figure 4 Lake Onslow Arch dam (Pioneer Energy)

Water from Lake Onslow is released into the Teviot River, where it supplies a series of small hydroelectric generators owned by Pioneer Energy. The 1.6 MW Michelle power plant runs on about 2.2 cumecs at 86% load factor. That suggest an average flowrate of about 2 cumecs down the Teviot river. The balance of the water input is accounted for by evaporation, evapotranspiration, recharging aquifers and trivial dam seepage.

Evaporative losses from the lake surface

The simplified Penman formula for evaporation from a body of water uses elevation, latitude, and temperature data. Using data from NIWA publications, the evaporation rate from Lake Onslow is estimated to be 3.2 mm/day, i.e., 1.2 metres/year. The evaporative loss from the existing Lake Onslow at 12 km^2 would be 0.44 cumecs, which is 14% of the annual average rainfall in the Lake Onslow catchment.

Migration of groundwater

The above estimates suggest that 60% of the annual rainfall in the Lake Onslow catchment area is currently discharged down the Teviot river and 14% of the annual rainfall evaporates from the existing lake. Evapotranspiration from the land surrounding the lake is assumed to be 10% of open water evaporation rate. Migration of ground water through the underlying schist rock to recharge groundwater is therefore estimated by difference to be in the order of 0.13 cumecs at present.

Figure 5 Estimated rainwater distribution

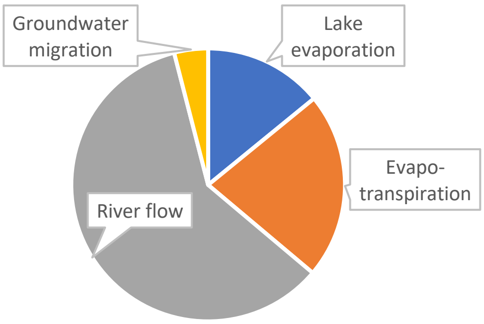
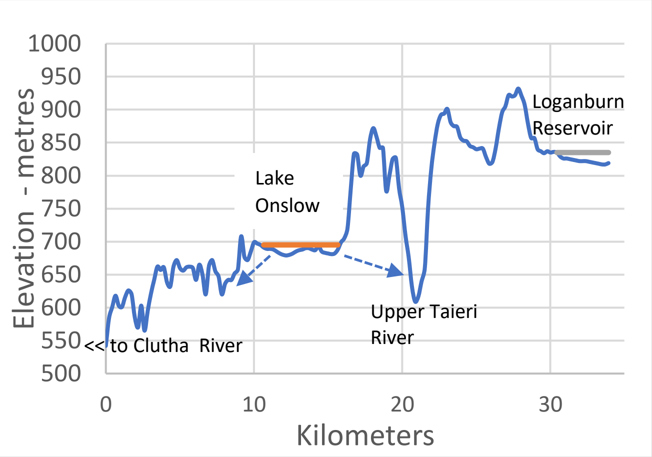


Figure 6 shows an east-west cross-section of Lake Onslow and its environs. The dotted lines show the potential for migration of groundwater.

Figure 6 elevations at S33º35' latitude



Ground water migration through the schist rock underlying Lake Onslow and its environs has been modeled using low-resolution data. The Darcy's Law model uses actual topography and heads to estimate the hydraulic conductivity of the schist, which is the principal unknown parameter.

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[6] https://niwa.co.nz/regionalclimatologies/otago

Using that model to back-calculate the groundwater migration of 0.13 cumecs from Lake Onslow gives a hydraulic conductivity parameter of 30 cm/day, which is consistent with fractured schist in regions with tectonic activity.

The spatial distribution of those estimates of groundwater migration is 90% to the west towards the Clutha River, 8% to the east towards the Upper Taieri River and 2% to the south. The Manorburn and Greenland reservoirs to the north are at higher altitude.

Effect of raised water level on water migration

If the level of Lake Onslow was to be increased to 760 m or 800 m the increased hydrostatic pressure on groundwater would increase the flow. There would also be an increase in groundwater flow due to the increase in the area of the lake. Preliminary modelling of those conditions indicates a five-fold increase in groundwater flow at 760 metres water level to 0.8 cumecs, or an eight-fold increase to 1.1 cumecs if the lake level is raised to 800 metres.

Effect of increased lake area on evaporation

As noted in Table 1, if the level of Lake Onslow is raised to 760 m the lake area would be 68 km^2. So the evaporative loss would be 2.5 cumecs; i.e. 80% of the annual typical rainfall. At 800 m level the evaporative loss from the lake would be 3.5 cumecs which is 11% greater than the annual rainfall. The increased areas of the lake would result in a corresponding reduction of lesser evapo-transpiration in the surrounding parts of the Lake Onslow catchment area.

Seepage through an earth dam

For the 800 m lake level, using the groundwater migration model, based on Darcy's Law and 30cm/day hydraulic conductivity parameter, the seepage through a 3km long earth dam with an average height of 56 metres, would be 0.1 cumecs.

For the lower lake level of 760 metres with a 1.5 km long earth dam that is 48 metres high on average, the seepage would be 0.04 cumecs.

Table 2 Summary of estimated water balances for Lake Onslow (average cumecs)

Water level (metres)	**695**	**760**	**800**
Rainfall in catchment	3.2	3.2	3.2
Evapo-transpiration	0.7	0.5	0.4
Lake evaporation	0.4	2.6	3.5
River flow	1.9	1.9	1.9
Dam seepage	-	0.0	0.1
Groundwater migration	0.1	0.8	1.1
Water deficit	**-**	**2.6**	**3.8**

The summary in Table 2 shows that if the level of Lake Onslow is raised to MBIE's level of 760 m, or Prof Bardsley's original level of 800 m, there will be a large increase in water losses such that a make-up of water would be required to maintain the elevated level.

Even if the flow down the Teviot River was to be completely shut off (with the corresponding loss of 60 GWh/year hydro output) the water saved would be insufficient to balance the water budget.

The MBIE plan for operating Lake Onslow as a dry-year storage facility with the range 720 to 760 metres, with Prof-Bardsley's updated features and the capacity to generate 3,200 GWh on demand would involve:

- The construction of a 1.5 km long dam.
- The construction of a 24 km tunnel from Lake Roxborough to Lake Onslow.
- The clearing of 27 km^2 of vegetation and soil from the inter-level flood plain.
- The installation of 1200 MW capacity generator/pumps at Lake Roxburgh.
- The use of 6,200 GWh of electricity for 6 months to pump 3.2 billion m^3 of water (40% of the flow of the Clutha River) up from Lake Roxburgh to fill the raised lake.
- The ongoing annual pumping of 81 million m^3 of water using 114 GWh/yr (twice the output of the Teviot River scheme).
- The use of 4,500 GWh of electricity to refill the lake after draw-down to 720 m.

If the frequency of dry-years is 1 in 8, then the total electricity input would be 5,400 GWh to produce 3,200 GWh output. The round-trip efficiency of the Onslow pumped hydro scheme would be 59%.

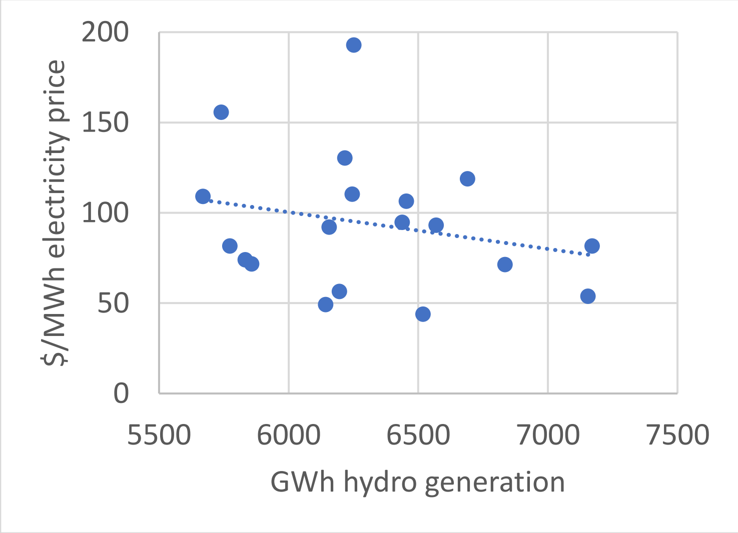
Lake Onslow Economics

The NZ electricity market is based on the principle that power stations are financed only from the sales of electricity, with no state subsidies of operating costs. Diurnal pumped-hydro schemes can be self-financing if the cost of electricity required to pump water uphill at night is substantially less that the revenue from sales of electricity during the day. For a diurnal pumped hydro scheme with 70% round-trip efficiency that can be achieved if the day/night price differential is 1.5:1 or greater.

In the case of the Lake Onslow scheme, with 59% round trip efficiency the electricity price differential between times of cheap plentiful supply to times of shortage of costly supply would need to be 1.7:1 or greater.

Figure 7 plots quarterly average NZ electricity prices from 2016 to 2020 against the quarterly hydro generation. This chart shows that there is no significant correlation between them. In the quarter with the least hydro generation the average wholesale price was $109/MWh, whereas in the year with the greatest hydro yield the price was $82/MWh.

Figure 7 Quarterly prices vs Hydro yield
(Data from MBIE 2016 - 2020)



That price differential of 1.33:1 is half that needed for the Lake Onslow scheme to break even on electricity cost alone. There is no potential for any return on the very large capital investment.

Filling the lake

SEF member, Dr Alastair Barnett *FEngNZ*, points out that the pumping requirement for the initial fill of Lake Onslow, or for refilling it after a large drawdown, would greatly exceed any surplus hydro capacity that might be available.

The annual production from the Clutha hydro schemes is about 3,750 GWh/yr. The chart on Page 1 shows that surplus generation in the 5 wet years averaged 8% of average production. So, it would take 20 wet years to provide the power to fill Lake Onslow to a level of 760 metres.

Diverting the whole Manapouri output, which is used by the aluminium smelter, would take 1.2 years to fill the lake plus new transmission lines.

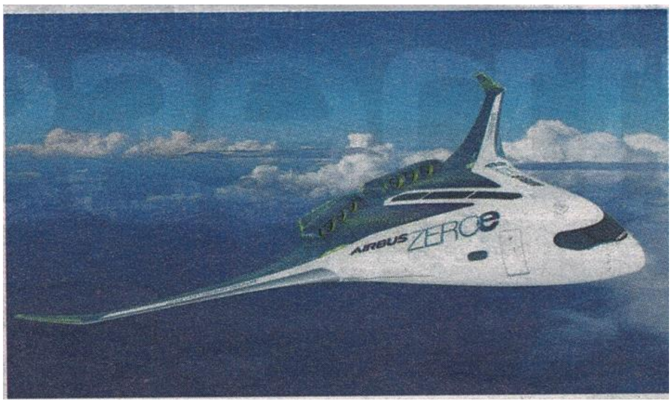
Providing enough electricity over 6 months to fill the lake would necessitate running gas and coal fired generation in North Island flat out.

Summary

- The scale of the original Lake Onslow scheme is 10 times larger than is needed to address the so-called “dry-year” problem.
- The scope of the project has changed: -
    - Level reduced from 800 m to 760 m.
    - Tunnel increased from 15 km to 24 km
    - Soil removal from 27 km^2 added
- The Teviot Valley dam would be 1.5 km long making it the second largest hydro dam in the world after the Three Gorges dam in China.
- The increased water losses due to seepage and evaporation would require permanent pumping to maintain the Lake Onslow level.
- The round-trip efficiency would be <60%
- The cost of electricity to fill Lake Onslow would exceed the revenue from electricity sales in a low-hydro year. So, there is no economic rationale to proceed.
- Filling Lake Onslow would create an electricity shortage in New Zealand of greater magnitude than the “dry-year” problem.
- **The NZ Battery Project should abandon the Lake Onslow concept forthwith without the need to proceed with re-estimating the capital cost of the ~$4 billion project.**

Hydrogen planes won't get off the ground

On September 23rd an article was published in the NZ Herald with the headline *"The tech that could clean up future of flight in NZ – Hydrogen fuel for Airbus models possible use for energy left by Tiwai Pt closure."* The article included this picture of a flight of fancy from Airbus engineers.



"Airbus concept for the world's first zero-emission commercial aircraft, which could be in service by 2035… a blended wing body design for up to 200 passengers."

The Airbus CEO is quoted as saying *"The concepts we unveil today offer the world a glimpse of our ambition to drive a bold vision for the future of zero-emission flight."*

After checking that the date of the newspaper was not April Fool's day, I did a few simple calculations and concluded that this was a classic example of the maxim - *if something sounds too good to be true then it probably is.*

Firstly, the projected 2035 date is far too late to address the short-term issue of stranded electricity due to the closure of Tiwai Point. Secondly, while I am reluctant to say 'never', I have concluded;

a liquid hydrogen fuel storage system would be too heavy to put in a commercial airliner.

Full fuel tanks in a typical commercial aircraft weigh about 30% of the maximum take-off weight of the plane. Take-off and climb to cruising altitude typically use 15% of the fuel. The descent and landing might need a further 5%. Hence, the minimum fuel demand for a flight is 20% of the on-board fuel. At 10% of fuel per hour for cruising, flights with jet fuel are workable and safe.

Hydrogen fuel is 2.8 times lighter than jet fuel for the same energy content. But there is a snag.

Liquid hydrogen must be stored under pressure at extremely low cryogenic temperatures; below the critical temperature of hydrogen; which is -240°C.

The Florida Solar Energy Centre compiled the following data on the status of hydrogen storage technologies in 2015.

The current status of various hydrogen storage technologies in terms of weight, volume and costs is given below. These systems show a three to eight times performance gap in meeting the DOE goals.

Storage technologies	***Weight kWh/kg***	***Volume kWh/l***	***Cost $/kWh***
Chemical hydrides	*1.6*	*1.4*	*$8*
Complex metal hydrides	*0.8*	*0.6*	*$16*
Liquid hydrogen	*2.0*	*1.6*	*$6*
10,000 psi gas	*1.9*	*1.3*	*$16*
DOE goals (2015)	*3.0*	*2.7*	*$2*

http://www.fsec.ucf.edu/en/consumer/hydrogen/basics/storage.htm

The net energy density of liquid hydrogen is 33.3 kWh/kg. Therefore, a liquid hydrogen storage system would weigh about 16 times the weight of the hydrogen it contains. If the US Department of Energy (DOE) goal of 3.0 kWh/kg can be achieved, then the hydrogen storage system would still weigh 10 times the weight of hydrogen fuel it contains.

In comparison, the net energy density of jet fuel is 12 kWh/kg. If the jet fuel tanks weigh 20% of the weight of fuel, then the jet fuel system would contain 10 kWh/kg, which is 5 times more energy than in an equivalent liquid hydrogen fuel system.

In a commercial aircraft design, replacing the jet fuel system with a hydrogen storage system of the same weight would carry one fifth of the energy.

Therefore, a hydrogen fuelled aircraft would consume all the fuel just to take off, climb, descend and land. *Steve Goldthorpe*

SEF's Climate Change Commission Submission

The Perils of pushing PHEVs

Submission

The aim of the Sustainable Energy Forum of Aotearoa Inc. (SEF) is *"Facilitating the use of energy for Economic, Environmental and Social Sustainability"*. SEF recognises the role that the efficient use of energy can play in addressing the contribution of New Zealand's CO_2 emissions to Climate Change in many different ways. In this submission SEF cautions the Climate Change Commission to avoid reliance on electrification of transport as a primary focus of Climate Action. Our "one big thing" issue is seen as a fatal flaw that can be fixed by some simple changes in the wording of advice to government. We also offer the Commission a simple cost benefit analysis (spreadsheet available on request) of electrification of light vehicles and conclude that that is a very costly strategy.

One Big Thing

"…. at least 50% of all light vehicle …… imports should be electric by 2027 (both battery EV and plug-in hybrid EV)" ***(page 108)***

This classification of Plug-in Hybrids as Electric Vehicles is a fatal flaw in the strategy to electrify the light vehicle sector in New Zealand.

Plug-in hybrids (PHEVs) are inherently more attractive than battery EVs (BEVs) because: -

- PHEVs have a lower capital cost than equivalent BEVs.
- PHEVs do not have the range limitations of BEVs.
- PHEVs do not have the inconvenience of requiring long distance journey planning because the high cost of fast chargers is similar to the equivalent cost of petrol.
- PHEVs do not suffer from range degradation as the battery ages, because the duty is seamlessly taken over by greater use of the petrol engine.
- PHEVs do not get to the point where an expensive battery replacement is necessary.
- PHEVs are typically large SUVs, which are favoured by NZ motorists.
- PHEVs should comfortably meet the 105 gm CO_2/km (5.5 l/100km) criterion as they age.
- As other countries transition to BEVs there is likely to be a glut of PHEVs with partially degraded batteries on the international used vehicle market.

If PHEVs are also given EV concessions or incentives (e.g. continued absence of Road User Charge) then there is a major risk that New Zealand will become a dumping ground for used PHEVs. A 6-year-old PHEV imported in the early 2030s is likely to still be in the NZ transport fleet in 2050, as an older family car. After 20 years the battery may have degraded to 20% to 30% of its initial capacity. It could still provide the hybrid function, but there would be little point plugging it in. Therefore, the older PHEVs would just become heavy petrol hybrids.

We recommend: -

- The EV concessions or incentives must not be given to PHEVs.
- The time limit on importing ICE vehicles by 2035, or earlier, must explicitly include a moratorium on importing PHEVs, on the grounds that they use fossil fuels.

Q. When is an EV not an EV?

A. When it's a PHEV

Analysis of real-world data for PHEVs finds that typical use worldwide is 37% on electricity for private use and 20% on electricity for business use. theicct.org/sites/default/files/publications/PHEV-white%20paper-sept2020-0.pdf

As time goes by, people will get lazy and batteries will deteriorate, so these numbers will reduce.

Cost-benefit analysis of light vehicle electrification

Replacement of conventional Internal Combustion Engine (ICE) vehicles with Electric Vehicles (EV) will result in a reduction in CO_2 emissions from the transport sector. However, EVs are more expensive than equivalent ICE cars, which raises the question **"What is the cost of CO_2 emission reduction by replacing an ICE with an EV?".** This cost-benefit analysis presents two case studies to address that question.

Basis of assessment

The whole-of-life capital and fuel costs are compared for identical models of the same vehicle, where the only difference is the automotive propulsion system. The auxiliary costs of tax, insurance, tyres, maintenance etc. are ignored for the purpose of this comparison. The whole-of-life basis will typically include the vehicle having several owners as it passes through the second-hand market with its value decreasing accordingly.

Towards the end of its life the range of an EV will reduce, which may inconvenience the user, but will not impact operating costs. EV battery replacement is not considered in this assessment.

Capital cost

Recent adverts for the Kia Niro present 4 engine options to the NZ market in 2021. The following indicative prices are sourced from the Kia website: -

ICE	$35,000
Hybrid	$40,000
Plug-in Hybrid	$56,000
Fully electric	$78,000

Indicative pricing from the Jaguar website compares Jaguar models.

E-Pace 2.0 litre ICE	$85,000
F-Pace PHEV	$100,000
I-Pace full electric	$150,000

Jaguar has announced both "mild-hybrid" and "plug-in-hybrid" versions in its F-Pace range, but a price for the "mild-hybrid" in New Zealand is not yet available. (p.s. The MG EV is only $21,500 more than its ICE direct equivalent.)

Manufacturing emissions

Lifecycle analysis of vehicle manufacturing is complex and case specific. A report from the Energy Centre at Auckland Business School reports the results of analysis of vehicle manufacturing in China. This study concludes that the manufacturing CO_2 emissions for an ICE car are about 10 tonnes and are about the same for an EV excluding the battery. When the energy demand of battery manufacture is added, the manufacturing CO_2 emissions increases to about 16 tonnes for an EV. This difference in manufacturing CO_2 emissions is included in this comparative analysis. The marginal increase in CO_2 emissions from battery manufacture for hybrids and plug-in hybrids are assumed to be 5% and 20% respectively of the marginal manufacturing CO_2 emission for a fully electric EV.

Other life cycle considerations of vehicle manufacturing, including resource demands and local pollutant emissions are important, but are excluded from this comparative analysis.

Lifetime fuel costs

The estimation of lifetime fuel cost is based on the following assumptions: -

- Petrol price = $2 per litre
- Electricity price = 25c/kWh. This is taken as the typical average retail electricity price in New Zealand. While some electricity might be sourced at lower cost, electricity purchased from fast chargers is more expensive.
- Petrol fuel consumption figures quoted on manufacturers websites are: -

Model	l/100 km	Model	l/100 km
Kia Niro ICE	5.0	Jaguar E-Pace	6.4
Kia Niro hybrid	3.8	*Mild hybrid*	*4.8**
Kia Niro PHEV	1.3	Jaguar F-Pace	2.4

*Jaguar offers a “mild hybrid” version of the F-Pace but no performance data is available. Therefore, a 25% reduction in fuel consumption compared with a conventional ICE is assumed, to match the hybrid advantage of the Kia Niro range.

The low fuel consumption data for PHEVs are determined on a new-vehicle basis for an urban cycle with a large proportion of the travel being short trips carried out using electricity. Real world data suggests that actual PHEV fuel consumption figures are typically about double these values because of higher mileage between recharging. Owners of PHEVs find that the high cost of electricity purchased from fast charging facilities means that the cost saving over petrol is marginal, so they typically only recharge overnight at their home base. As the battery ages the proportion of PHEV travel on electricity will reduce.

- Petrol calorific value = 34.5 MJ/litre, corresponding to 9.6 kWh/litre.
- The electricity consumption figures for EVs are determined as the ratio of battery size to nominal range. On this basis the Kia Niro EV uses 14.2 kWh/100 km (7 km/kWh) and the Jaguar I-Pace uses 23.6 kWh/100 km (4.2 km/kWh)
- The average vehicle lifetime is assumed to be 25 years, during which the vehicles are likely to pass through the hands of several owners with different needs.
- The average distance covered is assumed to be 15,000 km/year. Hence the average lifetime mileage of these modern vehicles would be 375,000 km.

Motor efficiencies and equipment degradation

The fuel-to-wheel energy efficiency of a non-hybrid ICE is assumed to be 35%. The charging cable to wheels efficiency of an EV is assumed to be 80%.

The energy efficiency of the PHEV set-up is calculated on the basis of the reduction in petrol use between non-plug-in hybrid and the PHEV being offset by electricity.

The degradation in overall fuel efficiency due to ageing of the mechanical components of both ICE and EV cars is assumed to be 0.5% per annum. Hence a 25-year-old car would have 13% higher fuel consumption than a new car.

The degradation of the battery in a PHEV would result in reduced range and hence greater use of the petrol motor. That degradation is assumed to be 5% per year. Hence a 25-year-old PHEV battery may have 28% of the capacity of a new PHEV battery. Nonetheless, the old PHEV vehicle would still be serviceable for hybrid duty and there would be no economic rationale for replacing the PHEV battery.

CO_2 emission factors

The tailpipe CO_2 emission factor for petrol is 2.45 kg CO_2 per litre of fuel.

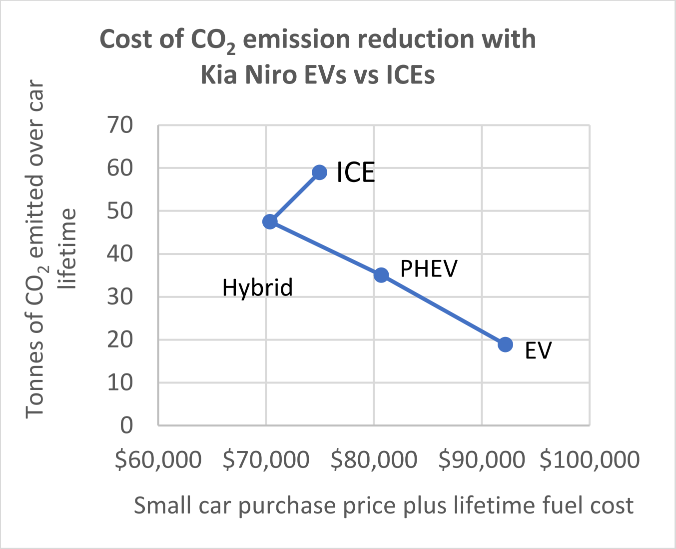
EVs have no tail pipe emissions, but electricity use in New Zealand has a composite CO_2 emission factor. The average MfE electricity emission factor from 2010 to 2015 inclusive was 0.142 kg CO_2/kWh. The average MfE electricity emission factor from 2016 to 2018 inclusive was 0.099 kg CO_2/kWh. These factors are based on the CO_2 emissions from fossil fuel power stations and geothermal power stations. It is intended the use of fossil fuels for power generation will be reduced in coming decades, but complete elimination of these sources is unlikely. Therefore, it is assumed that over the next 25 years the CO_2 emission factor for purchased electricity will average 0.05 kg CO_2/kWh.

Results of analysis

Figures 1 and 2 show plots of CO_2 emissions, including manufacturing emissions, versus capital and energy expenditure for the two vehicle models considered. The progressive electrification of vehicles from ICEs to hybrids to PHEVs to EVs results in reduction of CO_2 emissions. However, the cost of achieving those emission reductions is high.

Figure 1 shows that the emission reduction due to the transition from conventional ICE technology

Figure 1 – Kia Case Study



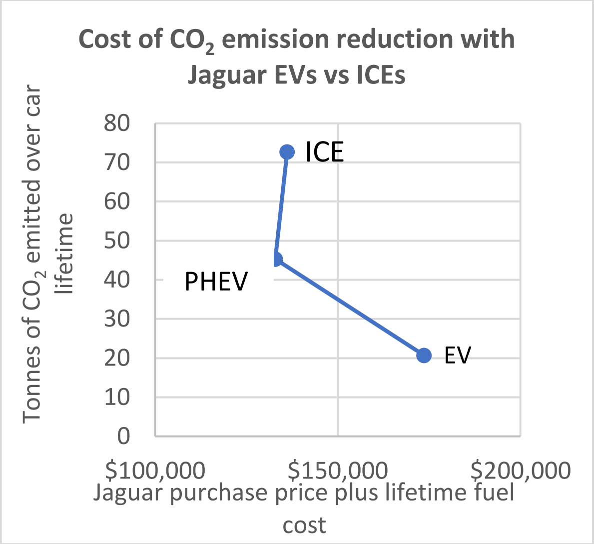
The cost of CO_2 emission reduction achieved by switching from a small hybrid to small EV is $761 per tonne of CO_2 emission avoided.

to hybrid technology achieves both savings in lifetime costs and CO_2 emission reduction.

However, the transition from a hybrid to a plug-in hybrid in the Kia Niro model costs $823 per tonne of CO_2 emission avoided.

This analysis also shows that additional battery capacity to transition from PHEV to EV costs $713 per tonne of CO_2 for the Kia Niro

Figure 2 Jaguar Case Study



The cost of CO_2 emission reduction achieved by switching from a Jaguar E-Pace to a Jaguar I-Pace is $720 per tonne CO_2 emission avoided.

and $1,652 per tonne of CO_2 for the Jaguar.

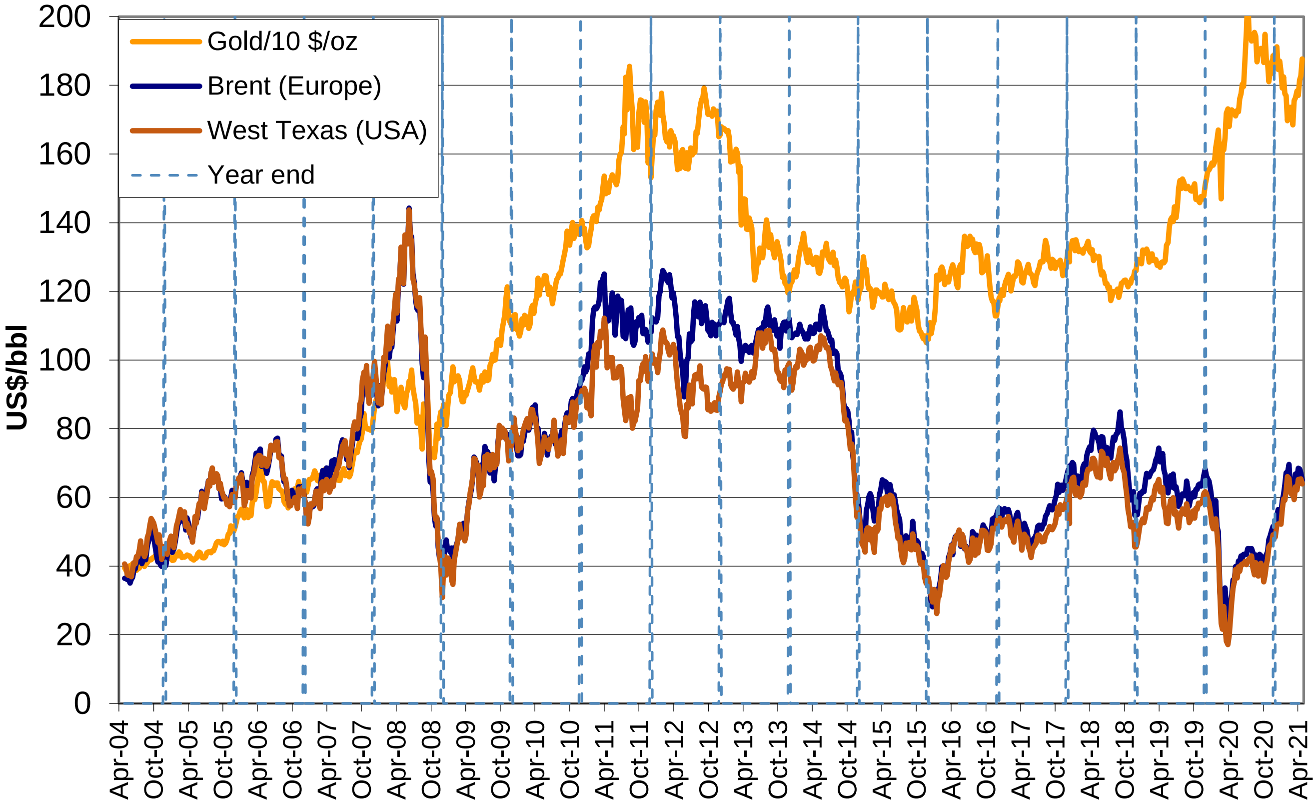
In the context of the carbon price increasing from the current $40 per tonne of CO_2 to a potential $250 per tonne of CO_2 emission avoided by 2050, the transition to electric vehicles is uneconomic.

Submission to Climate Change Commission on behalf of SEF

SEF member and EV advocate Peter Olorenshaw suggests that a sensitivity analysis of the assumptions underlying this analysis would test the robustness of the conclusion that EVs are a costly way of reducing CO_2 emission and won't be incentivised by a carbon tax alone. The table below shows the sensitivity to some key assumptions for the Kia Niro analysis for switching from a hybrid to a 100% EV, compared with the present-day analysis above, which returns a lifetime cost of $761 per tonne of CO_2 emission avoided.

Assumptions	Value for present-day analysis	Alternative values for adjusted analysis	Adjusted cost of CO_2 avoidance
Off-peak retail electricity price	25 c/kWh	15c/kWh	$563/tonne CO_2
EV electricity consumption	7 km/kWh	8 km/kWh	$693/tonne CO_2
Electricity generation emissions	0.5 $kgCO_2$/kWh	0.2 $kgCO_2$/kWh	$595/tonne CO_2
Marginal ICE maintenance costs	none	$100 per 10,000 km	$630/tonne CO_2
Combined cost of CO_2 avoidance	$761/tonne CO_2	$372/tonne CO_2	(all 4 together)-

Using an EV as a domestic uninterruptible power supply or mobile electricity supply, or for gaming the electricity market would impact its availability for personal transport compared with a conventional ICE. Expected reduction in battery costs should be reviewed from a holistic life cycle perspective. *Editor*



Neil's Oil Price Chart

IEA:Net-Zero-Goal-Means-No-More-New-Oil-And-Gas-Investment-Ever[7]

The world doesn't need any new investments in oil and gas beyond what is already approved if it hopes to achieve net-zero emissions by 2050, the International Energy Agency (IEA) said on 18th May 21, adding that the road to limiting global warming to 1.5°C involves a rapid and radical shift away from fossil fuels.

According to the IEA's pathway to net-zero emissions by 2050, the world will not need new oil and gas projects beyond those sanctioned as of this year, the Paris-based agency said in its Net Zero by 2050 report[8]

Instead, all new energy investments should be of the renewable variety in what the IEA refers to as an "immediate and massive deployment of all available clean and efficient energy technologies."

The agency's 'Roadmap for the Global Energy Sector' also says that no new coal mines or mine extensions are required if the world is to achieve net-zero emissions in 2050.

"The path to net-zero emissions is narrow: staying on it requires immediate and massive deployment of all available clean and efficient energy technologies," the agency said.

The scenario with the world reaching net-zero emissions by 2050 would mean a sharp decline in demand for fossil fuels, "meaning that the focus for oil and gas producers switches entirely to output – and emissions reductions – from the operation of existing assets," the IEA said.

"No new oil and natural gas fields are needed in the net zero pathway, and supplies become increasingly concentrated in a small number of low-cost producers".

"The pathway to achieving net-zero would result in coal demand collapsing by 90 percent by 2050 and natural gas demand slumping by 55 percent", the IEA noted. Oil demand would plunge by as much as 75 percent to just 24 million barrels per day (bpd) in 2050, from around 100 million bpd in 2019.

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[7] https://oilprice.com/Energy/Crude-Oil/IEA-Net-Zero-Goal-Means-No-More-New-Oil-And-Gas-Investment-Ever.html

[8] https://iea.blob.core.windows.net/assets/0716bb9a-6138-4918-8023-cb24caa47794/NetZeroby2050-ARoadmapfortheGlobalEnergySector.pdf

Join our sustainable energy news & discussion group

SEF membership currently provides a copy of our periodic EnergyWatch magazine. In addition, many members find the SEFNZ email news and discussion facility an easy way to keep up to date with news as it happens and the views of members. The discussion by the group of sustainable energy commentators who respond to the SEFNZ email service offers an interesting perspective.

The SEFNZ service provider has been changed from YahooGroups (SEFnews) to SEFNZ.Groups.io. Non-members are invited to join the SEFNZ email news service for a trial. To do this send a blank email to: SEF+subscribe@SEFNZ.groups.io. To help us stop spammers, non-members need to supply a name and contact details, and a brief statement of their interest and/or involvement in sustainable energy issues, before their trial is approved.

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EnergyWatch

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Readers are invited to submit material for consideration for publication.

Contributions can be either as Letters to the Editor or short articles addressing any energy-related matter (and especially on any topics which have recently been covered in EnergyWatch or SEFnews).

Material can be sent to the SEF Office, PO Box 11-152, Wellington 6142, or by email to editor@sef.org.nz, or by contacting the editor, Steve Goldthorpe, 309/9 Queen St, Warkworth 0910

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