EnergyWatch

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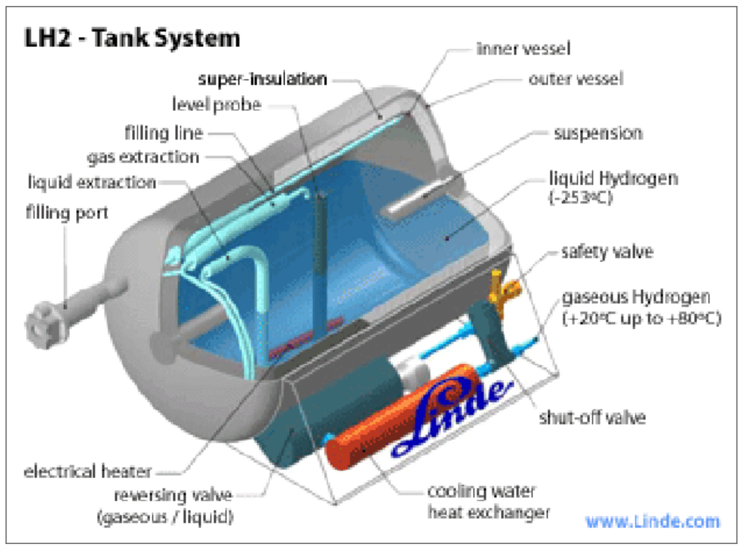
EDITORIAL

HYpeDROGEN

Issues with using hydrogen as an energy carrier

Promotion of the concept of a hydrogen economy in New Zealand is a fashionable front for a campaign by the oil and gas industry to lock NZ into dependence on natural gas and the consequent need for re-opening exploration for hydrocarbons.



Hydrogen is a valuable gas with unique chemical and physical properties. It is widely used in oil refineries and petrochemical plants and in various niche applications. However, the use of hydrogen just as an energy carrier is an inefficient waste of its potential. It is like using kauri as firewood.

The role of hydrogen in future energy systems has been widely canvassed with a fashionable enthusiasm. Superficially hydrogen is promoted as a carbon-free fuel. However, hydrogen is not a primary source of energy. It must be made from other primary energy resources involving either direct CO_2 emissions when it is made from fossil fuels, or reduced opportunities for alternative uses of electricity to offset fossil fuel energy use. When energy is converted to an intermediate energy carrier (i.e. electricity or hydrogen) significant conversion energy losses are unavoidable. In addition, hydrogen must be compressed to very high pressure, or reduced to the very low temperature of 20°K, for storage and transport as an energy carrier.

Nevertheless, the wordy promise of Hydrogen as the "energy source of the future" is heavily promoted. Hydrogen is particularly promoted to investors who for decades have made their fortunes through investment in the oil and gas industries. Such investors are becoming aware that oil and gas is a sunset industry where big profits are increasingly unlikely and risky, so they are looking for another big opportunity in the energy sector. Such greedy investors are ripe for being bamboozled by half-truths about exciting new technologies based on hydrogen. Likewise, NZ government departments are being enchanted by visions of a zero-carbon hydrogen economy, which ignore issues of inefficiency and fossil fuel support.

In this issue of EnergyWatch the properties of hydrogen as an energy carrier are compared with natural gas, ammonia, methanol, butane and gasoline as storable and transportable fuels that are needed to complement electricity as an energy carrier. The unusual properties of hydrogen pose challenging problems for its transport and storage.

Four hydrogen applications are compared with other means of providing the same service.

- The bulk storage of hydrogen to cope with occasional energy shortages is compared with the use of coal stockpiles or stored natural gas to achieve the security of supply of electricity.
- The peak-shaving storage of energy as hydrogen to help smooth out the daily profile of electricity demand is compared with the more efficient use of Li-ion batteries.
- It is suggested that an international market exists, particularly in Japan, for hydrogen produced from stranded renewable energy sources in New Zealand. This pipe dream doesn't stand up to rational analysis.
- Hydrogen fuel cell vehicles (HFCVs) are compared with electric vehicles (EVs) and hybrid petrol vehicles to explore the benefits and costs of alternative transport options.

None of these comparisons indicate a useful role for a hydrogen economy in NZ in the foreseeable future. While incremental improvements will occur, there are no likely technology breakthroughs on the horizon that might change the numbers significantly.

These issues are assessed in the context of the Full Fuel Cycle for the complete energy path from primary fuel to delivered energy services. The consequent cost of CO_2 emission avoidance in terms of \$/tonne of CO_2 is also estimated and found to be economically infeasible.

In the 1980's at Coal Research in the UK a study of "Hydrogen as an Energy Vector" concluded that there was no useful purpose for hydrogen in the role of an energy carrier. The physics, chemistry and thermodynamics remain the same today, as does the conclusion in the NZ context.

The Waste-by-Rail option for the proposed Auckland Regional Landfill is assessed.

In 2018, coal use at Huntly power station was 75% higher than in 2017. This seemingly unsatisfactory situation was due to a shortage of gas generation. In fact, the combined CO_2 emissions from coal and gas power generation reduced by 100,000 tonnes, mostly due to gas being replaced by hydro power. The output from wind and solar were unchanged. In that context, an argument for maintaining Huntly power station just in the role of emergency back-up generator of bulk electricity is presented.

The long-term outlook for renewable energy for bulk power generation in NZ is explored and finds that the outlook for each of the main renewable energy sources is limited. Electricity will need to be used frugally, particularly if it is to be used extensively in the transport sector. Wasteful use of limited bulk electricity supplies by converting it to and from hydrogen would be a grave mistake.

SEF made a submission on the MBIE discussion document "Accelerating Renewable Energy and Energy Efficiency", which is reproduced here.

This issue ends with the usual review of oil prices, which have fallen dramatically to a new low.

Steve Goldthorpe
Editor of EnergyWatch

CONTENTS

The properties of hydrogen

By Steve Goldthorpe

Hydrogen is a stable diatomic gas that does not exist naturally on Earth in useful amounts. Hydrogen gas is about 1 ppm in the atmosphere and is a minor component in some natural gas sources.

Chemically combined hydrogen by weight is 11% in water, 25% in methane or natural gas, 12-15% in crude oil, 6% in biomass and typically 5% in coal.

Hydrogen gas, for use as a chemical reagent, is almost all made on an industrial scale by steam reforming of natural gas or other hydrocarbons at about 60% energy conversion efficiency.

Hydrogen can also be made on a small scale by using electricity to split water (H_2O) into hydrogen gas and oxygen gas. Electrolysis of water converts energy from electricity to hydrogen with an energy efficiency of 60%. Higher energy conversion efficiencies are reported as being achieved using state-of-the-art Polymer Electrolyte Membrane (PEM) cells, but when compression and cooling of the hydrogen product is also considered, an overall energy conversion efficiency to a transportable H_2 fuel is likely to also be about 60%.

Hydrogen has specific applications in industry and some niche applications in other sectors. For example, the operators of the ammonia plant in Taranaki are considering making hydrogen from electricity for their process, probably due to uncertainty in their natural gas supply. Likewise, the Marsden Point refinery is considering converting electricity from their new PV plant to hydrogen to supplement their supply of process hydrogen.

Hydrogen embrittlement is a metal's loss of ductility and reduction of load bearing capability due to the absorption of hydrogen atoms or molecules by the metal. The result of hydrogen embrittlement is that components crack and fracture at stresses less than the yield strength of the metal. This effect is generally mitigated by lining hydrogen handling equipment. It is a particular problem for high stress equipment and makes the use of hydrogen in gas turbines problematic.

Compared with methane, hydrogen has one third of the volumetric energy density, which means that it would require three times the pipeline capacity for energy transmission at the same pipeline pressure.

Table 1 shows that hydrogen has a much wider flammability range than methane in air, so, in the event of a leak it could be more hazardous.

Transport and storage of hydrogen gas is problematic. It involves either extremely low temperature or very high pressure.

The picture on the front page shows an industrial liquid CO_2 storage vessel in which liquid hydrogen would be stored at 20 degrees above absolute zero, In a practical application, boil off of the stored hydrogen would need to be accommodated, which would be impractical in road vehicle applications.

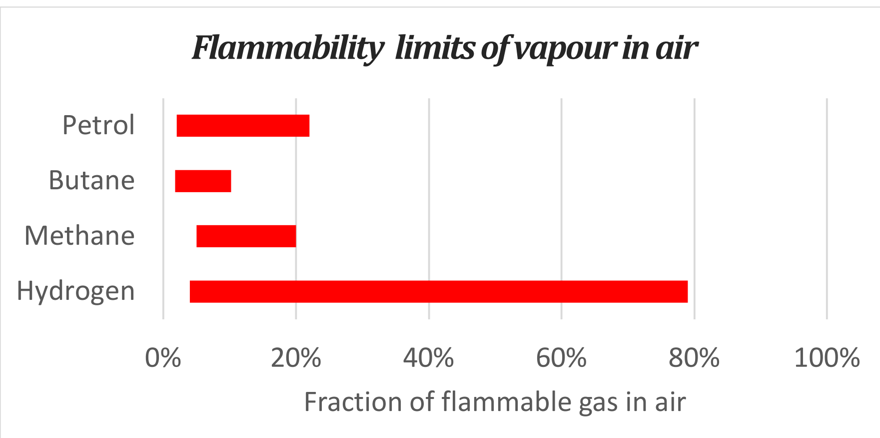
Hydrogen cars require hydrogen to be stored at ambient temperature and hence at a pressure of up to 600 atmospheres. Although the hydrogen molecule is very light, a multi-layer carbon-fibre-wound vessel to store hydrogen at very high pressure could weigh 15 to 20 times its contents. Table 1 shows that when the fuel container is considered the fuel storage system for a hydrogen car might be 7 times heavier than an energy-equivalent tank of petrol. Since a hydrogen fuel cell system is much more efficient than an internal combustion engine, that weight penalty might be reduced to a factor of 3.

If the primary energy source for making hydrogen is renewable electricity, then the use of hydrogen as a fuel will have the effect of producing less CO_2 emissions overall than alternative routes where fossil fuel is the primary energy source.

Comparison on a Full Fuel Cycle (FFC) basis, should be used to determine the net CO_2 emission avoided. Then the routes must be costed to determine their cost based on $/tonne of CO_2 emission avoided. Benchmarks are the current NZ carbon price of NZ$25/tonne of CO_2 and Carbon Capture and Storage schemes costing up to NZ$150 per tonne of CO_2 emissions avoided.

Table 1 The properties of hydrogen compared with some other fuel gases and liquids

	units	**Hydrogen**	**Methane**	**Ammonia**	**Butane**	**Methanol**	**Gasoline**
Boiling point °C	°C	-253	-162	-33.5	-0.5	65	50-180
Critical temperature	°C	-240	-82.5	132	152	239	~300
Molecular weight		2	16	17	58	32	80-160
Kinetic diameter	10^{-15}m	289	380	260	430		
Density at 15°C, 1 bar	kg/Nm^3	0.085	0.68	0.72	2.46	800	750
Liquid density	kg/m^3	71	420	548	575	796	730
Gross Calorific value	MJ/kg	141.8	55.6	22.5	49.6	22.7	47.3
Vol. Energy density at 1 bar	MJ/Nm^3	12	38	16	122	18,160	34,500
Storage pressure	bar	600	225	20	2.5	1	1
Density in storage at 20°C	kg/m^3	60	150	14	604	800	750
Volumetric energy density in storage (excluding container)	MJ/m^3	8,500	8,340	315	29,900	18,160	34,350
Mass energy density in storage (including container)	MJ/kg	7	8.8	7	28	20	48



In June 2019 a malfunctioning valve at a hydrogen refuelling station in Norway caused an explosion. Nobody was operating the equipment at the time but, people in a car that was passing by were injured by air bags, which were triggered by the blast. Valve design and testing has been improved.

The combustion of hydrogen in air could actually cause an implosion due to a reduction in the number of molecules: - $2\ H_2 + O_2 \rightarrow 2\ H_2O$.

The infamous Hindenburg disaster in 1937, in which the hydrogen-filled trans-Atlantic airship caught fire on docking in New Jersey, is the subject of much controversy. While hydrogen burned in the ensuing fire, it is unresolved whether or not the presence of hydrogen was the cause.

Bulk electricity supply – back-up options

Bulk Energy storage requirements

New Zealand's electricity supply is dominated by hydropower, which relies on regular rainfall. The storage of potential energy in lakes at high elevations is inadequate to cope with long dry periods, or equipment failures, for more than a couple of months. Back-up energy supply is important for New Zealand, which cannot import electricity from our nearest neighbour, Australia.

Three options for this duty are assessed: -

- Coal use at Huntly power station.
- Natural gas storage in the Ahuroa facility.
- 15% substitution of natural gas energy with hydrogen made from electricity.

The assessments below are based on the supply of 500 MW (>10% of peak NZ generation) for 60 days of back-up generation capacity to be used infrequently to accommodate unplanned shortages, such as dry year scenarios or other major electricity supply problems, which may occur 1 year in 3.

<u>Back-up with coal</u>

The Huntly coal-fired power station provides the capability to address the problem of abnormal shortage of electricity. The large energy resource is a coal stockpile, which does not degrade significantly over time. The remaining two 250 MW units of coal fired power generation capability at Huntly could provide an additional 720 GWh of back-up grid electricity supply, if operated on coal full time for 60 days. The corresponding CO_2-eq emissions on an FFC basis from burning 300,000 tonnes of coal (including coal mining and transport and mine methane emissions) using Assumptions I, would be 749 ktonnes of CO_2-eq. to NZ's greenhouse gas inventory for provision of the back-up generation service once every 3 years.

Assumptions I

- Power plant efficiency = 35% hhv basis
- CV of coal = 25 GJ/tonne
- CO_2 from coal = 92 kg.CO_2/GJ
- CO_2-eq from coal prodn. = 10% of combustion

<u>Back-up with natural gas</u>

The Ahuroa natural gas storage facility in Taranaki provides a large-scale store for processed natural gas for use in 2 existing 100 MW open-cycle gas turbine generators at Stratford, as required to meet seasonal shortages of electricity supply. The Ahuroa facility uses a depleted natural gas field at a depth of 2.3 km and with a storage capacity for 5-10 PJ of natural gas. To match the 500 MW back-up generation capacity of Huntly for 60 days, 7.4 PJ of natural gas would be required. Also 300 MW of additional open cycle gas turbine capacity, costing ~NZ$300 million, would be needed for back-up generation duty used once every 3 years.

7.4 PJ of natural gas would result in 384 ktonnes of direct CO_2 emissions. Methane leakage and emissions from gas production and storage (as in Assumptions II) would increase the total emissions from generation of 720 GWh to 506 ktonnes CO_{2eq}.

Assumptions II

- Open cycle gas turbine efficiency =35% hhv
- Open cycle GT capex = NZ$1000/kW
- Natural gas emission factor = 52 kgCO_2/GJ hhv
- Natural gas CV = 58 GJ/tonne hhv
- Natural gas CH_4 content – 83% by weight.
- CO_2-eq from gas prodn. = 15% of combustion.
- Leakage from Ahuroa = 0.7% over 3 years.
- Methane GWP = 86 (20-year basis IPCC 2013)

<u>Back up with hydrogen</u>

The green paper "A Vision for Hydrogen in New Zealand" suggests on page 45 that hydrogen might be used instead of natural gas as the fuel to be stored in geological gas storage facilities, such as Ahuroa, for occasional use for back-up generation. The green paper further suggests that the stored hydrogen gas could subsequently be used like natural gas in open cycle gas turbines to generate electricity when back-up supply is needed. That would be impractical because of the low volumetric energy density of hydrogen, the greater tendency of hydrogen molecules to leak and the problems with hydrogen embrittlement in gas turbines.

However, it might be practical to substitute a portion of the stored natural gas with hydrogen produced from electricity. For the purpose of assessing that option it is assumed that 15% of the energy content of the gas turbine fuel would be replaced with hydrogen.

The blended gas would occupy the 97% of maximum volumetric capacity of Ahuroa rather than 75% occupied by natural gas alone. The gas turbines would need to be adjusted to accommodate the lower CV gas and checked for embrittlement.

The natural gas requirement would be reduced from 7.4 PJ to 6.3 PJ. 1.1 PJ of hydrogen supplement would consume 514 GWh of electricity for electrolysis. The FFC greenhouse gas emissions reduces from 506 to 406 kt CO_2-eq.

Assumptions III

- Hydrogen calorific value = 141.8 GJ/tonne hhv
- Hydrogen off-peak production for 6 hours/day
- Hydrogen/gas store requires refilling in 1 year
- Electrolysis energy efficiency = 60% hhv
- Electrolysis equipment = $2000/kW

CO_2 abatement cost assessment

Generating the required back-up electricity with a natural gas system would reduce the FFC CO_2-eq emissions from 749 to 505 ktonnes CO_2-eq per back-up generation event. If 15% of the gas supply is replaced with hydrogen, then the FFC emission would be further reduced to 430 ktonnes CO_2-eq. However, substantial new investments in equipment would be required.

Additional gas turbine infrastructure costing $300 million might be used 10 times over its 30-year life, i.e. $30 million per occasion that the back-up generation facility is used.

The cost of water electrolysis units is estimated to be about NZ$2000/kW of electricity consumed. To generate 1.1 PJ of hydrogen in 1 year with off peak power for 6 hours every night would require 235 MW of electrolysis capacity costing $469 million.

Table 2 shows that the use of gas instead of coal for this duty would cost $173 per tonne of CO_2 emissions avoided. That cost would increase to $238 with the substitution of hydrogen. For comparison, Carbon Capture and storage (CCS), typically costs under NZ$150 per tonne of CO_2 emission avoided. CCS schemes are not being actioned in NZ. of course, whilst the carbon price remains at around NZ$25 per tonne CO_2.

Replacing the coal stockpile with a biomass store at Huntly power station with modified burners, would have a much lower cost per tonne of CO_2 emission avoided than these gas storage schemes.

Therefore, there is no appropriate role for government to assist in facilitating the use of hydrogen in the long-term energy store for back-up electricity supply in New Zealand.

Table 2 Comparison of schemes to provide 500MW of electricity generation 24 hours per day for 60 days once every 3 years

	Coal at Huntly	**Natural Gas**	**85% Natural Gas + 15% H_2 from electricity.**	
Power generation technology	Steam turbines	Gas turbines	Gas turbines	
Overall CO_{2eq} emissions	749 ktonnes	506 ktonnes	430 ktonnes	0
CO_2 emission avoided	-	243 ktonnes	309 kt CO_2	
Input fuel	7.4PJ coal	7.4 PJ gas	6.3 PJ gas	514 GWh elec
Fuel price assumption	$5.25/GJ	25 $/MWh	25 $/MWh	3c/kWh
Fuel cost	$38.9 million	$51.4 million	$44 million	$15 million
Additional investment	0	$300 million	$300 million	$469 million
Capex repayment per occasion		$30 million	$77 million	
Additional cost per event		$42 million	$97 million	
Cost of CO_2 emission avoidance	**$/tonne-**	**$173**	**$238**	

Hydrogen as a peak-shaving technology?

Surplus electricity can be converted into hydrogen via electrolysis and that hydrogen can be converted back into electricity with a fuel cell. Therefore, hydrogen technologies have the potential to consume low cost surplus electricity when it is available and produce high-value electricity during the day at times of peak demand.

However, an alternative and more efficient means of delivering the same service would be the use of a Lithium Ion battery storage system.

As noted above, the efficiency of conversion of electricity to hydrogen via electrolysis is typically about 60% and the efficiency of converting hydrogen to electricity in a fuel cell process is about 70%. Therefore, the round-trip energy storage efficiency would be about 42%. Technology improvements might improve that round-trip efficiency to 50% in the long term. Nonetheless, even with a 50% roundtrip efficiency there needs to be at least a 2:1 price difference between day and night electricity just to cover the energy loss.

In contrast the round-trip efficiency of a Li-ion battery system can be up to 90%. So, a 2:1 price difference between day and night electricity would provide a big margin to fund the battery storage system and make it economic.

The Tesla Powerpack delivers a <130 kW power and capacity for <232kWh. In a 2-hours each way cycle, the round-trip battery system efficiency is 88%. (https://www.tesla.com/en_NZ/tesla-powerpack) Indicative pricing for the Tesla Powerpack in the USA is US$1000/kW.. A price in NZ might be about NZ$200,000 for a 100kW input unit.

If a Powerpack unit were to be charged at 100kW for 2 hours per day the off-peak electricity at 3c/kWh would cost $6 per day. The delivered energy would be 176 kWh. If sold at 25c/kWh, that peak power would be worth $44 per day. If operated 5 days per weeks for 50 weeks per year, it would take 21 years to repay the capital coats of the battery pack on a simple pay-back basis.

Meeting the same input duty with hydrogen would require a 100kW water electrolysis unit. At $2000/kW the water electrolysis equipment would cost $200,000. At 42% round-trip efficiency 42kW of fuel cell capacity would be required. At $2000/kW the fuel cell equipment would cost $84,000. The electricity cost would be $6 per day but the peak rate revenue would only be $21/day. Under the same operating regime, it would take 76 years to repay the capital cost of the hydrogen production and use equipment, which is not viable.

Both Li-ion battery storage and hydrogen storage systems are carbon-free. In the context of daily peak shaving of electricity supply the assessed hydrogen system would be grossly uneconomic and wasteful compared with Li-ion battery storage.

Therefore, there is no appropriate role for government in facilitating the development of hydrogen to assist with daily electricity load management in New Zealand.

Hydrogen as an internationally traded commodity?

The world's first liquid hydrogen transport ship was launched in Japan by KHI in October 2019. (https://newatlas.com/marine/kawasaki-worlds-first-liquid-hydrogen-transport-ship) The Suiso Frontier is 116-meter long and will soon be fitted with a vacuum-insulated, double-shelled liquid hydrogen storage tank capable of holding 1,250 cubic meters of liquid hydrogen at 20°K. That cargo would be 0.013 PJ, which is 0.2% of the energy payload of a Panamax LNG tanker. If scaled up to that size, a liquid H_2 tanker would carry 3.4% of the energy.

The intended source of hydrogen for supply to Japan is brown coal gasification in Australia. The embodied CO_2 of hydrogen produced that way would be 235 kg CO_2/GJ, plus transport emissions. That is more than twice the embodied CO_2 of coal.

If stranded electricity from closing Tiwai Point was to be made into hydrogen for export to Japan, a $2 billion investment would be needed. The hydrogen would cost much more than hydrogen could be produced in Australia. **This pipe dream doesn't stand up to rational analysis.**

Hydrogen vehicles – pros and cons

Compared with conventional vehicles, both HFCVs and EVs have the marketing advantage of no tailpipe CO_2 emissions, but the cost of that CO_2 emission reduction would be excessive. HFCVs can be refuelled much faster than EVs, but if the hydrogen is made from electricity and then converted back to electricity in a fuel cell in the vehicle, that introduces a large energy loss. It would be cheaper to make the H_2 from natural gas.

HFCV's and EVs are compared in Table 3 with a hybrid petrol car to travel 300 kilometres on the open road. All these vehicles would include the efficiency benefit of regenerative braking.

Hybrid petrol car

Using the assumptions listed below, a hybrid car would use 15 litres (11kg) of petrol costing $19.5 before tax, with FFC emissions of 37.9 kg CO_2-eq.

Electric Vehicle

In comparison a battery electric vehicle might require an overnight charge of 51 kWh to deliver 300 km of motoring the next day. That would cost $7.65 at an off-peak $15 c/kwh tariff. However, the battery electric vehicle would cost $20,000 more than an equivalent petrol hybrid vehicle to buy.

Hydrogen Fuel Cell vehicle

The efficiency benefit of fuel cell use is detailed in the assumptions below. 1.56 kg of hydrogen would be required for the same duty as 11 kg of petrol. Table 1 suggests that the hydrogen tank could weigh an additional 30kg.

An on-board hydrogen fuel cell would be used in combination with an EV battery to accommodate the varying vehicle load and regenerative braking If the 1.56 kg of hydrogen is consumed over 4 hours of vehicle operation for 300 km of open road driving then a fuel cell with a capacity for consuming 0.39 kg/hr (15 kW) H_2 would be required. At 70% efficiency the fuel cell output would be 10 kW. At a fuel cell price of $2000/kW, the fuel cell unit in an HFCV would cost $20,000. Hence a hydrogen car might cost $40,000 more than an equivalent petrol hybrid vehicle to buy.

HFCV costing with H_2 from natural gas

If the hydrogen is produced from natural gas then, the hydrogen price might be $2/kg. However, distribution and retailing of hydrogen is assumed to be $4/kg. So, hydrogen cost would be $9.4 per fill.

21.9 kg of CO_2-eq emissions would be associated with the production of 1.56 kg of hydrogen from natural gas.

HFCV costing with H_2 from domestic electricity

If hydrogen is made by domestic scale electrolysis of water, then there would be no CO_2 emissions. The electricity required to make 1.56 kg of hydrogen would be 103 kWh. A domestic electrolysis unit operating for 6 hours at night would be a 17-kW unit. At $2000/kW that unit might have a capital cost of $34,000.

At a domestic off-peak electricity tariff of 15 c/kWh the energy cost would be $43.3 per fill.

Assumptions IV

- Fuel consumption 5 litres per100 km
- Petrol CV = 47.3 MJ/kg
- Hydrogen CV = 142 MJ/kg
- Petrol density 0.73 kg/litre
- Petrol emission factor 66.6 kg CO_2/GJ
- CO_2-eq from petrol prodn. = 10% of comb.
- ICE-hybrid petrol to wheel efficiency 28%
- HFCV hydrogen to wheel efficiency = 59.5%
- EV electricity to wheel efficiency = 85%
- Gas reforming CO_2-eq = 14kg per kg H_2
- H_2 prodn. cost from CH_4 = $2/kg
- H_2 distribution and retailing = $4/kg
- Off peak electricity tariff = 15c/kwh
- Fills over 10-year life of car = 500

Lifetime costs

A typical car or small van might be expected to achieve a lifetime mileage of about 300,000 km on average. Therefore, it would require 1000 energy refuelling fills at 300 km per fill. On a simple capital payback basis, compared with a petrol hybrid vehicle, the additional capital cost component of vehicle use would be: -

- $20 per fill for an EV,
- $40 per fill for an HFCV that is refuelled at a filling station and
- $74 per fill for an HFCV that is refuelled with hydrogen made at home from off-peak electricity.

Table 3 shows that when the higher capital cost of an EV is considered the total cost is greater than a petrol hybrid car. The benefit of CO_2 emission reduction is similar to the cost of CCS.

In the case of an HFCV the cost per 300 km is higher again particularly if H_2 is produced from off-peak retail electricity. The cost of reduction in CO_2 emission would be more than 10 times that of CCS.

For large vehicles the outcomes would be similar.

Table 3. Comparison of schemes to deliver 300 km of travel in a modest vehicle

	Hybrid car	**Electric car**	**Hydrogen fuel cell car**	
Primary energy source	Fossil petrol	Renewable Electricity	Natural gas reforming	Renewable Electricity
Primary energy demand	15 litres	51 kWh	1.56 kg H_2	1103 kWh
Energy price (exc. tax, + distrib.)	$1.3/litre	15 c/kWh	$6/kg H_2	15 c/kWh
Operating cost per fill	$19.5	$7.65	$9.4	$15.5
Additional capital cost per fill	-	$20	$40	$74
Energy and capex cost per fill	**$19.5**	**$27.5**	**$49.4**	**$89.5**
Overall CO_{2eq} emissions per fill	37.9 kg CO_2-eq	0 kg	16 kg CO_2-eq	0 kg
CO_2-eq emission avoided		37.9 kg CO_2-eq	16 kg CO_2-eq	37.9 kg CO_2-eq
$/tonne of CO_2-eq avoided	**-**	**$211**	**$1870**	**$1850**

This analysis shows that HFCV vehicles are not effective for achieving low-carbon objectives at a viable cost. In addition, it shows that the production of hydrogen from natural gas is much cheaper than making it from electricity by electrolysis. However, using natural gas as the source of hydrogen would lock NZ into long-term dependence natural gas with the consequent need for re-opening exploration for hydrocarbons or importing LNG, which run contrary to aims of the Zero Carbon Act policy objectives for NZ climate response.

Therefore, there is no appropriate role for Government in facilitating the development of hydrogen fuel cell vehicles in New Zealand.

Jeanette Fitzsimons

Jeanette Fitzsimons (1945 - 2020) was a long-standing member of SEF and regularly shared her vision and values at SEF conferences and discussions. She was first and foremost an activist, i.e. a leader through taking positive action, despite achieving the detached respectability of a Government minister. One thing that she regretted never achieving in her life was getting arrested.

As Nandor Tancos said at Jeanette's memorial service held in her valley in the Coromandel *"A mighty Totara has fallen letting light through to the saplings,"* There are many young activists who were guided and inspired by Jeanette. Her spirit will live on in their values and passion.

A Role for Rail in NZ

By Steve Goldthorpe – Warkworth Resident

Since moving to Warkworth, I have become aware of a strong NIMBY sentiment surrounding the proposal to develop the Auckland Regional Landfill (ARL) in the Dome Valley, with landfill has a 25 million tonne design capacity. Auckland Region's Municipal Solid Waste (MSW) would likely be placed in the ARL from 2026 to the early 2040s. There is scope for taking a further25 tonnes over rhe subsequent 15 years. The main concern of my neighbours is leachate in the Hoteo river. However, my focus is on the transport of MSW from Auckland.

Location of Proposed Auckland Regional Landfill

The traffic assessment in the Resource Consent application estimates the addition of over 300 waste truck trips each way per day up SH1.

Based on the data in Assumptions boxes, the total emissions that would arise from diesel trucks delivering 25 million tonnes of MSW from Auckland would be 130,000 tonnes of CO_2eq over the life of the landfill consent from 1.72 PJ of diesel. If fuel cell trucks used 5,718 tonnes of hydrogen. It could be made from 375 GWh of off-peak renewable electricity produced with a 12 MW ($24M) electrolysis plant over 15 years. The cost of 50 trucks costing $12M might double.

Waste by rail

The map opposite shows that the Northern rail line passes within 3 km of ARL. KiwiRail have cited tunnel heights, tonnage limits and scheduling difficulties as barriers to persuing the *"waste by rail"* option. Transporting 25 million tonnes of waste by electric train would require 42 TWh. A 3 km spur to ARL might cost $55 million by scaling down the cost of the Northport rail link and assuming that infrastructure would also serve the second tranche of waste accommodation at ARL. Upgrading the rail line to ARL is half of the planned rail upgrade to Whangarei.

Table 3 shows that use of hydrogen trucks might be an economic way of reducing emissions, as would *'Waste by Rail';* depending on the capital cost of the short rail line spur to ARL.

Assumptions V

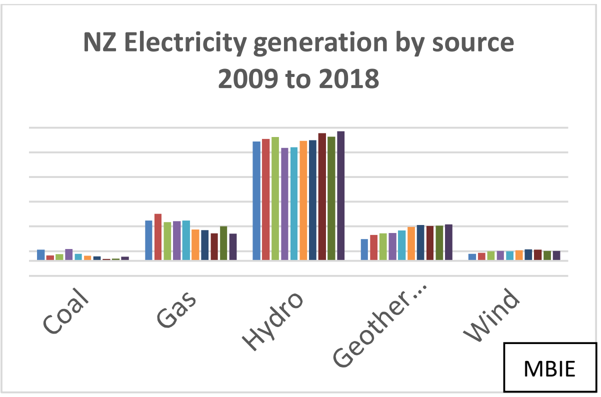
- Truck loading 42 tonnes, full 17 tonnes empty
- Diesel 31 l/100 km full and 25 l/100 km empty
- Truck trips 80 km each way
- Diesel 38.1 MJ/l, 68.7 kg CO_2/GJ
- CO_2-eq from diesel prodn. = 10% of comb.
- Diesel engine fuel to wheel efficiency = 33%
- HFCV hydrogen to wheel efficiency = 59.5%
- Gas reforming CO_2-eq = 14kg per kg H_2
- Rail fuel consumption = 25% road fuel cons
- Cost scaling exponent = 0.7

Table 4. Comparison of schemes to transport 25 million tonnes of waste to ARL

	Diesel trucks	Hydrogen trucks	Electric train
Primary energy source	Fossil diesel	Renewable Electricity	Renewable Electricity
Primary energy demand	45 million litres (1.7 PJ)	375 GWh (1.35 PJ)	42 GWh (0.15 PJ)
Energy price (exc. tax, + distrib.)	$1.3/litre	8 c/kWh (off-peak)	15c/kWh (day rate)
Energy operating cost	$58 million	$30 million	$6.3 million
Additional capital cost	-	$36 million	$55 million
Total cost per 25 million tonnes	**$58 million**	**$66 million**	**$61.3 million**
Overall CO_2-eq emissions	130,000 tonnes	0 kg	0 kg
$/tonne of CO_2-eq avoided	**-**	**$61**	**$25**

Where to for Huntly Power Station?

The recently published annual *Energy in New Zealand* report shows a 75% increase in coal use at Huntly power station in 2018, compared with 2017, whilst the generation from renewables remained constant. Those data raised the question *"How is this situation compatible with aiming for a low-carbon electricity industry?"*



This chart shows the production of electricity by energy source over a 10-year period. Although coal use in 2018 was 75% greater than in 2017, the longer-term picture is a decline in coal use.

In 2018, there was a shortage of natural gas, due partly to production outages at Pohokura. Fortunately, in 2018 hydroelectric output was at a record level which compensated for three-quarters of the gas shortfall. The rest of the gas shortfall was met by coal-fired power generation at Huntly, in its design role of being NZ's back-up generator.

Genesis Energy has pledged to stop using coal to generate electricity except in exceptional circumstances by 2025, and to stop using coal entirely by 2030.

Genesis Energy's Huntly Power Station is a thermal power station that can use coal, gas or both simultaneously as fuel. (*Radio NZ 14 Feb 18)*

The outcome in 2018 was an example of the use of coal at Huntly fulfilling its primary design purpose of acting as large back-up generator, to keep New Zealand supplied with electricity when other sources temporarily prove inadequate. If Huntly power station as a back-up generator is phased out, then there is a risk that in low hydro years, or when there are equipment failures, electricity shortages and blackouts would occur.

Householders living off-grid using solar PV, small wind turbines and maybe a micro hydro to meet their electricity needs would still be prudent to have a petrol generator in the shed for when energy supply problems arise with the weather or with their renewables installation. New Zealand, as an isolated island community, is no different. NZ cannot hook into emergency electricity supplies from Australia on a bad day.

The competitive electricity market in New Zealand requires all sources of electricity to compete equally on price alone. In that market framework the operation of Huntly on coal in a back-up role only is not viable. Hence Genesis is planning to phase it out. The short-term gaming of the market by participants, causing shortages to boost prices is the only mechanism by which coal and gas generation can be viable. It means that the electricity market fails to deliver a sustainable outcome for security of supply and fails to address low-carbon objectives or fair and stable pricing.

A mechanism that might address this inadequacy of the electricity market could be to recognise the value of Huntly power station as a special case large scale on-call energy store for New Zealand, which is only to be used under specific adverse circumstances. The cost of maintaining that emergency-only capability would then need to be funded from the levy that the Electricity Authority puts onto NZ power bills. That would reduce CO_2 emissions from coal to as little as necessary and would open the electricity market to investment in the wind and solar farms and geothermal plants, which are required for long term low-carbon sustainability as discussed next.

Steve Goldthorpe

Outlook for energy sources for bulk electricity generation

The aspirational long-term vision of the electricity supply industry in New Zealand is to double the production of electricity by 2050 and for that power to be produced without the use of fossil fuels. How realistic is that goal and what primary sources of energy would be required?

A secondary question is how would load-following, both day-night and summer-winter be achieved? Hydro is the only renewable energy source that can load-follow. The others would require bulk energy storage requirements. These matters can only be addressed once the future balance of primary energy sources are identified and quantified.

The chart opposite shows that bulk energy sources for power generation are Hydropower, Natural Gas, Geothermal and Wind. These are discussed below. Combined heat and power schemes also contribute to the electricity supply, but they are driven by the host industrial heat applications, with the electricity output being a by-product.

Nuclear power is not an option for New Zealand.

Tidal and wave energy as a source of bulk electricity has the potential to make a contribution in New Zealand, but only in the long term, See http://www.awatea.org.nz/marine-energy/

Solar photovoltaic (PV) electricity is suited for production at small scale and low voltage at the end-use location. Bulk generation in remote PV farms, involving transforming to high voltage and transmission losses, is unlikely to be attractive compared with local PV generation and use.

Electricity demand in NZ has only increased at a rate of 0.13% per year over the last decade. When the aluminium smelter closes it will release about 15% of NZ's electricity onto the market, which would be enough for 100 years of growth at that low rate given updated transmission capacity to transmit that electricity to other loads in NZ.

Doubling power generation by 2050 would involve a higher growth rate of 2.3% per year, which is plausible with a rapid uptake of electric vehicles in NZ. If that electricity demand were to eventuate how would the energy be sourced?

Hydropower

The chart opposite shows that 2018 was a record year for hydro generation. Since no new dams have been built, this suggests an effect other than normal dry-year/wet-year variability - possibly attributable to Climate Change.

Reliance on increasing hydro for more electricity supply may be short-sighted. The capacity of hydro lakes is supplemented by run-off from snowmelt and rainfall. Two effects of climate change are glacier retreat and increased rainfall. However, as the snow cover on the mountains is depleted, that legacy of potential energy from snowmelt will decline and the timing of rainfall is unpredictable. In the long-term, hydro availability and reliability with existing dams and lakes may decline.

Natural gas

Likewise, reliance on natural gas for electricity supply is short-sighted. Natural gas is a declining by-product of oil prospecting and production. In view of the moratorium on new licensing for oil prospecting, the supply of natural gas and its reliability will decline in the long term. That will help the zero-carbon objectives but will require alternative sources of stored energy for load-following power production.

Geothermal

There is some scope for expansion of base-load electricity generation from geothermal energy in NZ. The chart opposite shows a steady growth in Geothermal electricity generation over the last decade. However, geothermal resources involve CO_2 emissions, which may need to be captured and reinjected in a zero-carbon future.

Wind

The early growth of wind power plateaued and has recently declined. Further investment in wind is being held up by uncertainty over the closure of the aluminium smelter. Furthermore, unpredictability limits the practicable proportion of wind power in the electricity mix.

Steve Goldthorpe

SEF submission on the December 2019 discussion paper
ACCELERATING RENEWABLE ENERGY AND ENERGY EFFICIENCY

This submission concludes that the MBIE discussion paper only considers energy supply for industry and bulk electricity generation. It does little to support or encourage the growth of direct renewable energy use and energy efficiency in New Zealand and ignores energy use initiatives at the small consumer level.

The discussion paper's executive summary begins with Government's "aspirational goal of 100% renewable electricity". It does not mention the qualifier "in a normal hydro year", nor the fact that the six or more peaking stations in MBIE's electricity scenarios require an assurance of gas supply, which in turn requires a separate base-load user, on long-term contract, to keep gas flowing through the gas processing facility. The "100% renewable" claim is simply false.

New Zealand's "Renewable Energy Strategy" and work programme has eight elements: Renewable Electricity Generation, Process Heat, Green Hydrogen, Resource Strategy, Just Transition work, Electricity Price Review, Gas Act changes, and Backing Emerging Technologies. The MBIE discussion document covers only the first two elements.

New Zealand no longer has an energy policy to provide a useful framework for this discussion. The Ministry of Energy, a public service organisation with a focus on social, environmental and economic benefits, has been replaced by the Ministry of Business Innovation and Employment, effectively driven by the business sector, and focussed only on economic benefits. The dominant policy focus of MBIE is deregulation and big business profit – expressed today as "industry self-regulation".

Essential energy services are provided by profit-maximising entities whose shareholders demand growth. The direct consequence of this single-minded approach is that energy prices rise to whatever the market will bear, regardless of affordability. Environmental protection is reduced to the minimum statutory requirement.

Many residential electricity consumers who can afford to invest in energy efficiency and/or solar are doing so. With the industry proposed removal of "low-user tariff" and a new $2/day electricity fixed charges for network services, many more consumers will add their own large batteries to their PV systems and disconnect from the grid, as this will become economic for them to do so. This will be to the detriment of the shared electricity supply model that benefits everyone. Meantime, many of those who are less affluent must choose between "heat or eat".

Industrial electricity prices are typically half residential prices, with so-called "export exposed" industries receiving the biggest discounts. A prime example is the aluminium smelter. Huge increases in residential electricity prices have created high profits for the energy companies on the pretext that they are needed for the funding of new centralised power stations, despite minimal electricity demand growth since 2007.

Transpower crystallised the electricity industry's vision in its recent report Te Mauri Hiko, of doubling New Zealand's generating capacity by 2050. This current MBIE discussion document is single-mindedly designed to support that electricity industry growth path vision.

SEF considers that New Zealand needs real regulation to replace today's industry self-regulation, which is supposedly overseen by the Electricity Authority, and constrained by the Commerce Commission. A Ministry of Energy, or preferably an independent Energy Commission, is needed to create a new framework to analyse investment and pricing, including the introduction of new technologies, to meet New Zealand's energy needs efficiently while minimising environmental consequences and excessive costs to householders. Its analysis of demand and supply scenarios must be fully transparent and open to public consultation.

Such analysis would facilitate distributed energy supply and energy efficiency providers to offer their energy services into the marketplace, with corporate electricity and gas suppliers required to co-operate rather than compete to minimise their costs.

Today small-scale energy businesses cannot compete because of predatory pricing, where the corporates segment the markets to maximise the revenues from those consumers who have little choice. Strong regulation would identify and sanction such strategies.

Several models of electricity regulation adapted for different ownership and regulatory regimes have been devised by the Regulatory Assistance Project (RAP), who advise many US regulators, and now advise several European countries, China and India. A special issue of the Electricity Journal edited by RAP gives a comprehensive picture of regulation to optimise an energy economy. Unfortunately, the document lies behind a big paywall. An outline of each of the papers is given in RAP's link to a lengthy webinar (free) discussing the articles and giving a link to the abstract of each article:

https://www.raponline.org/blog/clean-flexible-and-efficient-a-recipe-for-energy-optimization/

SEF members attended a recent Bioenergy Association workshop which identified further evidence to support the more extensive use of wood energy:

• Ministry for the Environment reports that the emissions budget requires 13 million tonnes abatement over 5 years. They note that the lowest-cost option is energy efficiency, followed by fuel switching to biomass. Waikato University puts abatement costs of biomass at around \$50-\$100/tonne CO2, compared to electricity for steam or direct heat >\$150/tonne CO2.

• Scion has updated its wood resource inventory. Using conservative assumptions, they have identified wood energy could supply over 20 PJ/year. Complaints by some in the energy industry that wood supply is unreliable are unjustified given the extensive development by the Bioenergy Association on standardising wood fuel supply and supply chains.

• Pellets are the most reliable fuel for smaller heat requirements, costing in order of 7c/kWh in bulk, or a mere 12c/kWh in bags for household use – around half the cost of electricity. Further diffusion of biomass in heat-using facilities is a key means to reducing carbon emissions for New Zealand.

• The National Environmental Standard on Air Quality (NESAQ) is a major barrier to use of wood energy in homes, industry, and especially education facilities and hospitals. NESAQ must control PM2.5 instead of PM10 which has much less health impact. It must control annual not daily pollutant levels, as the cumulative impact on health is greater than acute impact. European air quality standards are far more effective than New Zealand's. Evidence from Christchurch shows that hospital admissions increased, not decreased, as PM10 levels decreased following implementation of the Air Plan. In fact, the admissions correlated well with the use of diesel vehicles in the city.

SEF recommends that: -

1) The blinkered approach to grounding energy policy on the mechanisms of the competitive electricity market should be rejected.

2) A change in philosophy and a new holistic regulatory system is needed, designed to minimise climate-changing consequences of energy choices while also minimising energy supply costs to small consumers.

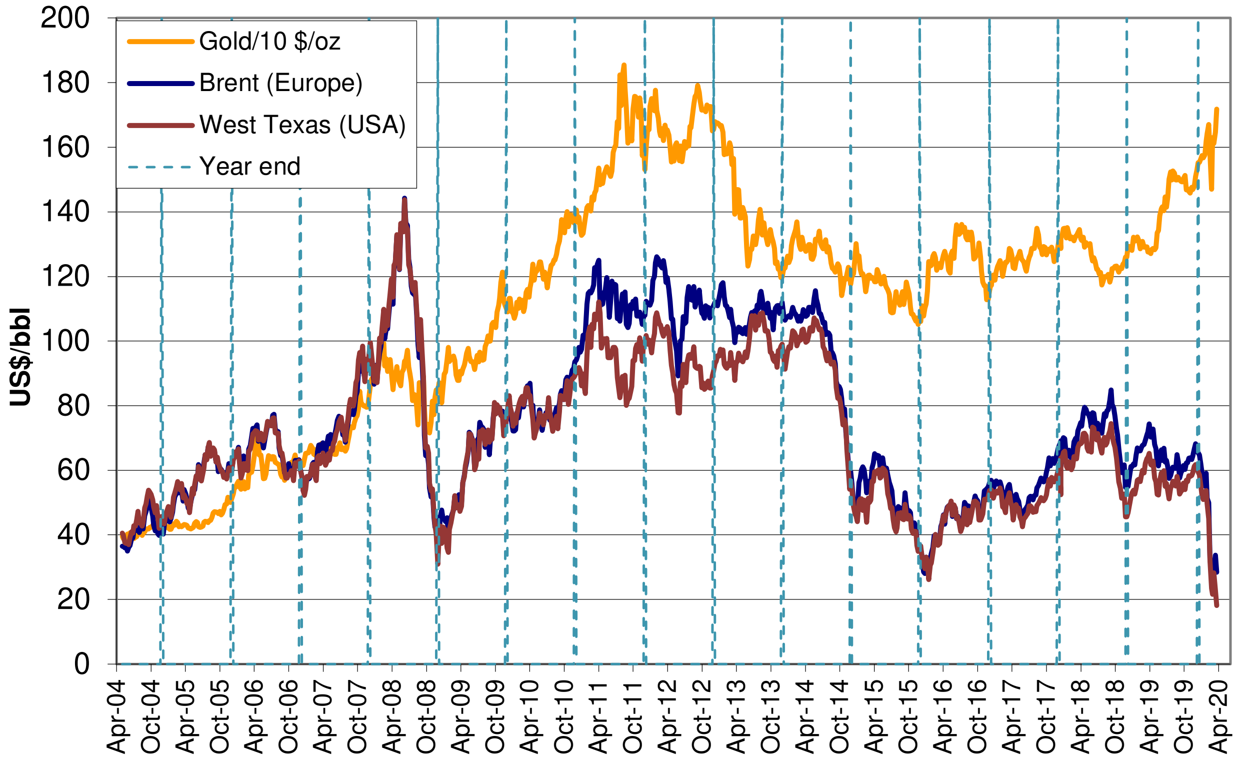
3) Employment and economic well-being should be sought through the necessary transitions to efficient use of renewable energy in New Zealand.

4) Wood quantities are enough for a major expansion in wood for process heat.

5) SEF supports option 3.1 in the discussion paper: "Expand EECA's grants for technology diffusion and capability-building.", with a particular focus on bioenergy.

6) The National Environmental Standard on Air Quality is a severe obstacle to wood energy: it must be revised to align with European standards.

Submitted on behalf of The Sustainable Energy Forum Inc. by Ian Shearer, SEF Office Manager



Neil's Oil Price Chart

Abridged commentary from Tom Kool, editor Oil Price .com (to Oil Industry investors)

As oil markets descend further into chaos, Big Oil has lost billions, independent producers are filing for bankruptcy, and entire economies are on the brink of collapse. Investors are now looking at the wreckage of the last few months, scrambling to find bargains.

If the history of the so-called "Great Recession" of 2008-9 is to be believed, while the current carnage in the energy space will negatively impact a lot of people, both investors and those in the industry, it will create some tremendous opportunities for those with the ability to take big risks. At some point, this too shall pass and when it does, it will become clear that some stocks were massively oversold on the way down. The problem is not just that crude prices are being hit at the same time as the coronavirus shutdown kills demand. It is also that a lot of energy companies came into this with massive debt loads. That presents an obvious, immediate short-term problem of servicing the debt as revenues dry up, but there is another, bigger, long-term problem that for many could prove to be an existential threat.

The security for those loans is usually oil and gas reserves, and those reserves are worth a lot less now than they were just a few months ago. In the case of oil, the value of the loan collateral has dropped by over sixty percent in three months. Natural gas holdings have halved in value since November of last year. In theory, that doesn't really matter that much to the borrowers until the loans come due and need to be refinanced but is still has the feel of a ticking time bomb for some smaller energy companies. The problem for investors in energy is that it means that even after the current crazy times are behind us, there will still be companies facing problems.

Of course, that wouldn't be the case were prices to recover rapidly, but that looks unlikely. It is not that oil can't or won't recover, it's just that even a major retracement will take time and could easily still leave crude at significantly lower levels than it was when the existing loans were arranged. The situation with natural gas is, if anything, even worse. The recent drop there was part of a longer-term steady but large decline in prices, suggesting that even if a cure and vaccine for coronavirus were found tomorrow, poor old natty would still be depressed.

Tom Kool, Editor, Oilprice.com

Join our sustainable energy news & discussion group

SEF Membership currently provides a copy of our periodic Energy Watch 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.Gropups.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.

SEFNZ emails can be received "individually" (as they are sent) or as a daily summary (grouped into one email per day). Emails can be switched on and off, or read via a website, which is a handy option for travelling Kiwis. Groups.io saves all our text emails for later reference, and there is a search function so that you can review the emails stored since the changeover. For further details contact the administrator <office@sef.org.nz> to help set up your profile.

EnergyWatch

Publication is now periodic, and EnergyWatch is posted on the SEF website (www.energywatch.org.nz) as a PDF file, shortly after individual distribution to SEF members.

Contributions Welcomed

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, at PO Box 96, Waipu 0545.

SEF membership

Memberships are for twelve months and include EnergyWatch.

Membership rates are:

Low income/student	$30
Individual	$50
Overseas	$60
Library	$65
Corporate	$250

Mail the form below, with your payment or order, to The Sustainable Energy Forum Inc., P O Box 11-152, Wellington 6142. Bank transfers, with your name, can be sent to the SEF account at 03-1538-0008754-00, with a confirming email to office@sef.org.nz.
A receipt will be sent on request.

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