WHAT OPPORTUNITIES ARE EVIDENT FOR GEOTHERMAL WITH THE LOSS OF KIWI GAS?

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ABSTRACT

The New Zealand Government's April 2018 decision to stop petroleum exploration bidding outside Taranaki will reduce the amount of energy that the oil and gas sector will produce in New Zealand. This will create an increasing shortfall in supply of indigenous gas production against current demand of 200 PJ/a (56 TWh/a).

This paper will outline what opportunities are likely to be available for geothermal companies on the back of these changes as a supply/demand gap emerges. It will show that as the gas market shrinks, different gas customers will take different decisions on what capital investment best fits their business.

Small high value gas markets will remain with gas while electric generation, industrial heating and commercial uses will shift to alternatives. As geothermal electricity generation currently solely provides baseload generation, the challenge for geothermal will be to replace mothballed gas baseload and diversify into higher margin peaking services.

1. GAS ENERGY USE

1.1 Historical Gas Production

Gas was discovered at Kapuni in 1959. This discovery kicked off development of the resource for use in electricity, industrial heating and residential heating.

In 1969 the Māui gas field was discovered and the country's electricity system morphed from being a hydro-dominated system to a mainly gas and hydro system. Unfortunately, the oil price shocks of 1970's meant that forecast growth was far short of actual electricity growth. The solution for this large demand gap was the development of the Motunui gas to gasoline plant. This brought in the era of large petrochemical manufacture underwritten by cheap gas. Smaller producers such as the Ballance urea plant and the Waitara methanol plant all contributed to a diverse gas market.

The history of gas demand in Figure 1 shows electricity has been the main demand followed by industrial and non-energy (gasoline/methanol) use.

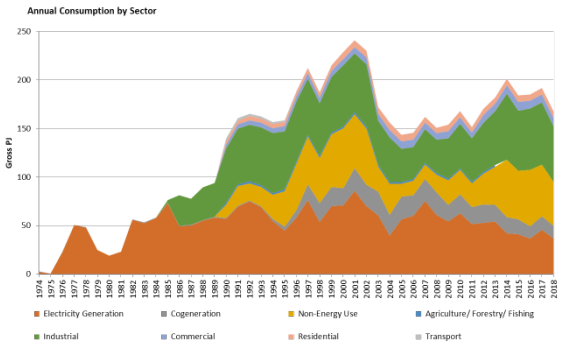

Figure 1. New Zealand Gas History by Demand Sector (MBIE/Elemental)

1.2 Gas Industry Fundamentals

A general rule for the petroleum industry is "you either put money in or you are going out of business". Every day of production is another step towards the end of field life, unless of course you find new reserves. To find new reserves, you must explore.

Exploring for oil and gas is a high-risk undertaking with only ~10% of wells being commercial discoveries. If you find something, you can then use additional capital to develop the reserves and produce them. Finally, when those reserves are depleted you must decommission the wells and facilities which have been built.

Taranaki is currently the only commercial basin for oil and gas production in New Zealand. In April 2018 the NZ Government stopped issuing new exploration permits, excluding onshore Taranaki.

1.3 Gas Forecast

The 2019 Ministry of Business Innovation and Employment (MBIE) forecast of annual gas production is shown in Figure 2.

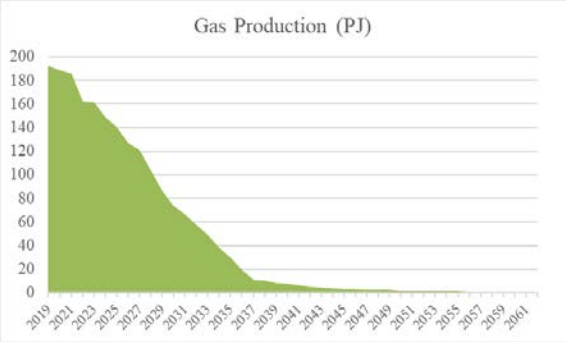

Figure 2. New Zealand Gas Forecast (MBIE/Elemental)

Figure 2 is the "most likely" production forecast and drop from 190 PJ in 2019 to 10 PJ/a in 2037 with a long tail thereafter to zero in 2061. While there are contingent resources in New Zealand which may become economic due to changes in technology and commodity prices, these have not been included.

2. Electricity Use

2.1 Demand Sectors

Transpower forecasts electricity demand to double over the next thirty years (Figure 3). This is caused by general growth offset partially by improved efficiency, conversion of industrial and commercial heat to electricity and new growth coming from the switch to electric vehicles.

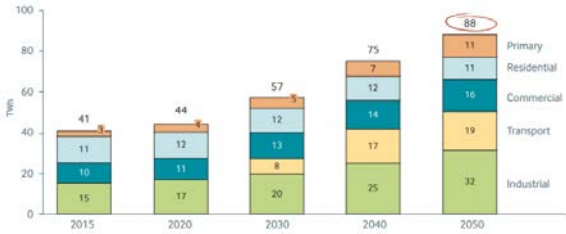

Figure 3. Forecast Energy Demand over Thirty Years (Transpower)

In 2015, the largest user of electricity was the industrial sector followed by residential, commercial and a fairly small primary industry demand. By 2050, transport is expected to be the second largest electricity user with transport demand starting to become significant during the next decade.

2.2 Electricity Supply

New Zealand produces about 155 PJ/a (44 TWh/a.) of electricity. The majority of this is from hydroelectric lakes, followed by gas, geothermal, coal, wood and wind (Figure 4). All of these sources have their own supply characteristics.

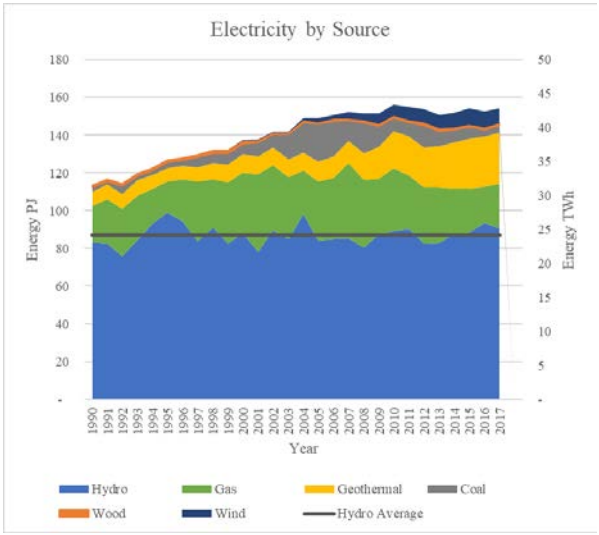

Figure 4. New Zealand Electricity Production by Source (MBIE/Elemental)[1]

Hydroelectricity is controllable to some extent, but ultimately hydro generation is defined by the total inflow of NZ precipitation and snow melt into southern lakes.

2.3 Electricity Volatility

2.3.1 Decadal

Weather patterns are variable in New Zealand. The varying precipitation shows up as volatility in power production from hydroelectric production and this variance is shown in Figure 5. The average annual production is 86 PJ (24 TWh) and dry years are represented by the orange underproduction. This production variance is 5.6 PJ/a (1.6 TWh).

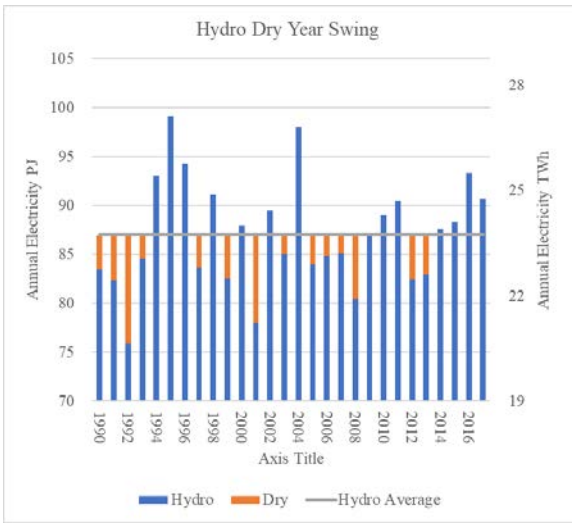

Figure 5. Variance in hydro production over 28 years (Elemental)

The power system deals with this by using gas and coal as swing supply in dry years. While the total amount of electricity produced by gas and coal has fallen over time, they are still used as dry year reserves.

2.3.2 Seasonal Volatility

Electricity demand increases during winter periods as increased heat load is required for residential, commercial and industrial sectors. This swing is represented in the way that hydro storage, the largest contributor to electricity generation, is used throughout the year and outlined in Figure 6. The grey line represents the 91-year average while the light blue and dark blue lines represent storage levels for 2018 and 2019 respectively.

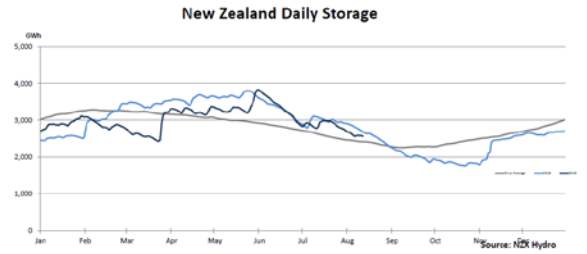

Figure 6. Daily Hydro Storage in New Zealand (NZX Hydro)

The average grey curve is higher in quarter 1 of the year as lower demand allows filling of the lakes. During quarter 2 and 3 the lakes are depleted as higher offtake is used. During winter, precipitation is captured as snow in the catchment of the South Island hydro lakes. The increased inflow occurs during spring (quarter 4) as the snow melts, flowing into the southern hydro lakes.

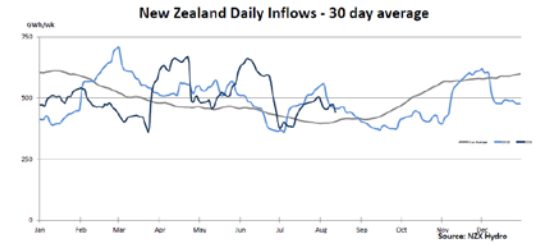

Figure 7. NZ Daily Hydro Inflows (NZX Hydro)

The inflow patterns are shown in Figure 7 with a slightly higher inflow over quarters 1, 2 and 4 compared to quarter 3 where inflow is restricted due to snow fall.

2.3.3 Daily Volatility

With the loss of gas firming for electricity generation over the coming two decades, it is expected that wind, solar and geothermal will fill this gap.

While geothermal is a stable generator of electricity, wind and solar are not. Wind generally produces around 50% of its capacity with periods around days. Solar on the other hand produces about 15% of capacity, peaking around midday and producing no electricity during night.

The overlay of these two power sources will cause interesting production patterns which are still being understood for issues such as grid stability.

Hydro and gas generation are particularly well suited to provide the 'swing', or peaking capacity, in the daily demand cycle. Increase in intermittent renewables, wind and solar will create scenarios where national peaking requirements will be larger. With the loss of gas generation, geothermal generation could fill the peaker 'gap'.

Hydroelectric generation can be switched up and down rapidly (within 6 seconds), thereby making it ideal for being dispatched by the System Operator in times of rapidly changing demand. This is known as peaking. Additionally, this makes hydro-electricity ideal for participating in the Fast Instantaneous Reserve Market (FIR).

The difference between maximum and minimum load is shown in Figure 8. The load on this day peaks at 6,100 MW at 1700 hrs and is at its lowest point of 3600 MW around 0400 hrs.

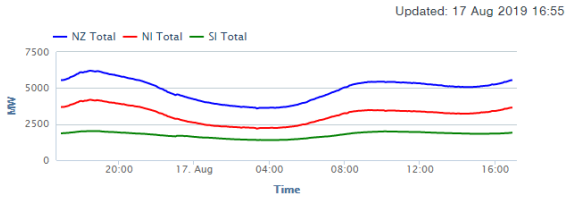

Figure 8. Daily electricity load cycle (Transpower)[2]

New Zealand's System Operator (SO), Transpower, predicts this cycle to less than 2% error (SO Monthly Load Accuracy Forecast Report).

Wind and solar generation, however, have irregular generation profiles which can be difficult to predict. Wind and solar are offered into NZ's electricity wholesale spot market as an 'always dispatched' product. This poses the dual problem of both timing and magnitude upon the daily demand cycle. Mini peaks and troughs may occur throughout a daily demand cycle as the SO tries to balance the nation's demand minus the intermittent generation. In this new daily demand curve, peaking capacity requirements could become larger and more stressed.

New Zealand's wholesale electricity market dispatches energy by order of price merit. The SO matches the nations generation to demand in real time and sends instructions to the generators to generate more (or less) every 5 minutes. Generators must offer their full potential generation into the market in tranches priced according to their willingness to generate at particular price points. This is the Wholesale Spot Market. If a demand peak occurs, the market energy clearing quantity increases through the tranches and the spot price is set by the last MW of energy dispatched. All MWs dispatched will receive this spot price. Typically, hydro, thermal and gas generators position their tranches in the region where the national dispatch will settle. A future with reduced/high priced thermal and gas generation will vacate those price points currently held, leaving hydro to perform this marginal dispatch function. In dry years hydro tranches become smaller and also price up.

3. Is Geothermal Only Suited to Baseload Power Generation?

3.1 Geothermal recharge

Stefansson (2000) explains that the energy current from the interior of the earth is the primary source of geothermal energy in Iceland. This takes place by three processes:

♦ advection of magma

♦ advection of geothermal fluid, and

♦ thermal conduction.

Energy (heat) transport with the advection of magma and thermal water is a relatively fast process. Time constants in the range of days or months are suitable to describe these processes. On the other hand, thermal conduction is a relatively slow process where a time constant of the order of hundreds of years is needed to characterise the process.

In New Zealand, there are no active magma processes (i.e. surface volcanoes) around New Zealand's electricity generating geothermal fields. Therefore, heat transfer is via conduction and convection. The graphical model presented by O'Sullivan (2012) is shown in Figure 9.

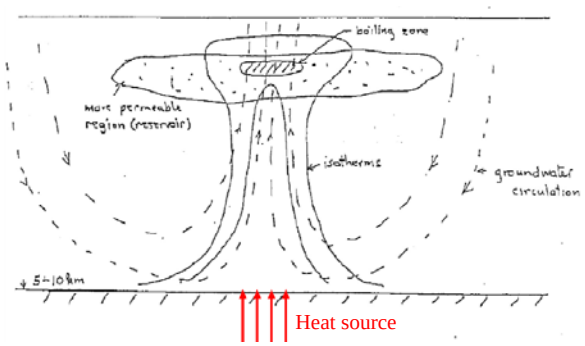

Figure 9. Schematic of main heat transfer mechanisms in New Zealand geothermal fields (O'Sullivan)

Simulation modelling of recharge times at Wairakei was completed by O'Sullivan and is shown in Figure 10. The field is shut in at 2050 after a hundred years of production. In the western borefield it takes 150 years to return to 220ºC. On the eastern borefield it takes 400 years to reach 210ºC.

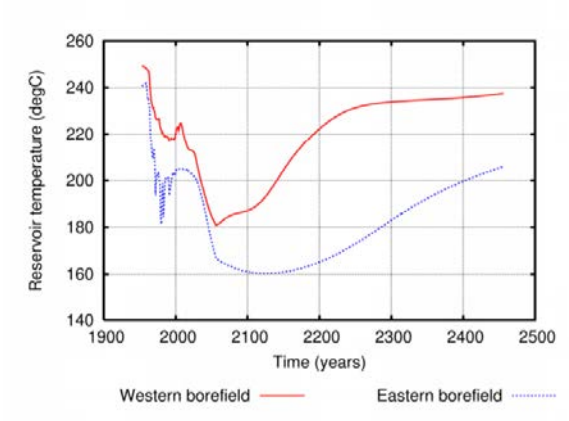

Figure 10. Wairakei Temperature Modelling (O'Sullivan)

3.2 Non-continuous offtake

Most fields were designed to operate near steady state operations with a small amount of swing. The following is an explanation of how the McLachlan (aka Pohipi East) Field operated.

"A separate power plant (McLachlan a.k.a Poihipi) in different ownership was permitted and commissioned in 1996 on the western side of the Wairakei resource. The initial application was filed under the WSCA in 1988, but because of extensive litigation consents were not issued until 1995. Much of the litigation arose through having two competing users on the same resource, not only potentially affecting each other but also potentially having additive impacts on effects with consequent liability issues. The plant had a generating capacity of 55 MWe but was limited by the daily steam take permitted by consents and could not generate at full capacity for a full day. The owners elected to operate at full capacity at times of daily peak demand (and peak spot prices) until the daily allocation was almost used up, then dropping back to 3 MWe generation overnight. Despite its technical success and this novel approach to the market, the project was a commercial failure with the company going into receivership and the plant being purchased by the other operator on the field, Contact Energy. The original owners of the McLachlan project later applied for in 2001 and were granted consent in 2006 for 60,000 T/d from an adjacent property, and drilled one deep well, but the project has not proceeded further."[3]

In terms of delivering swing capacity, this appears to be a technical success but a commercial failure.

Hawaii has developed a new geothermal plant with flex generation. The new BoP/Kawerau- Te Ahi O Māui plant has a resource consent with flexibility and Contact Energy have requested amendments to Wairakei resource consents to make operation of their geothermal plants more flexible (personal comms Bart van Campen).

3.3 A Benefit of Intermittent Production

A benefit of intermittent production in terms of sustainability is that a field can have an "infinite" field life, requiring only oversizing of the plant and regular (over 500 years) facilities upgrades. Using the Wairakei average restoration period of ~300 years with a 100-year field life, the following facilities offtake profile can be taken for the 2 GW geothermal electricity industry supply.

Offtake Factor	Annual Production	Peak Production	Field Life
100%	7.2 TWh	2 GW	100 years
50%	3.6 TWh	2 GW	200 years
25%	1.8 TWh	2 GW	∞

4. The Value of Peaking

4.1 Gas Price Sets Electricity Price

Sustained dry periods known as "dry years", highlight the role of gas generation when ensuring security of supply for NZ's electricity market.

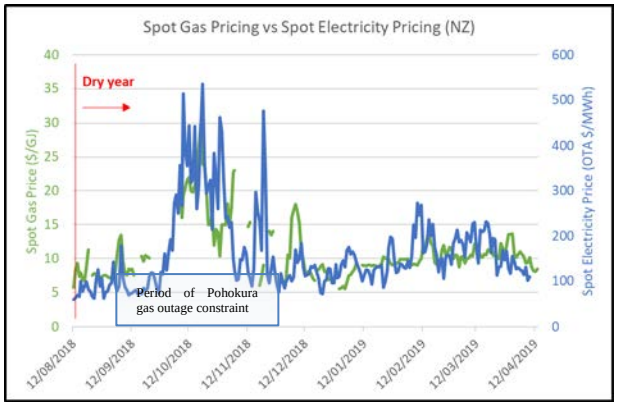

Figure 11. Gas and electricity spot prices during the 2018 dry year with Pohokura gas outage

Figure 11 above clearly shows a correlation between the wholesale spot gas price and the wholesale spot electricity price. National hydrology from mid-2018 was low and gas production from Pohokura was halved in October, November and December 2018. The correlation becomes closer during this period as the gas (fuel) price set the electricity (product) price.

4.2 New Zealand Market for Instantaneous Reserves

New Zealand's electricity reserve market ensures grid stability in the event of a sudden drop in supply (generator trip, HVDC failure) and comprises two products. Fast Instantaneous Reserves (FIR) and Sustained Instantaneous Reserves (SIR). To compete in the FIRs market the generator must offer MWs that can be dispatched within 6 seconds and run for 60 seconds. For SIRs the requirement is to be on within 60 seconds and run for 15 minutes. Hydroelectric is ideally suited to provide FIRs as the generating unit can ramp up as rapidly as the wicket gates can open. Hydroelectric and gas generators are well suited to provide SIRs. The National Reserve Market has provision to supply reserves across the HVDC, thereby linking the North and South Islands and making available New Zealand's large hydroelectric reserve capability. Prices in the reserve market are low in comparison to the electricity spot market however there are occasional price spikes. There may exist a possibility for flexible geothermal to compete in the reserve market, however additional investment to satisfy the required flexibility would need to be tested against the 'less than' buoyant reserve market.

4.3 Other Baseload and Peaking Considerations

New large-scale hydro is expected to be difficult to build. The NZ Electricity Efficiency and Conservation Authority (EECA) state that, regarding hydroelectric generation, 'the major opportunities have already been taken, and (as) there is keen public interest in preserving our waterways, large projects are unlikely.'

Genesis, operator of the Huntly coal fired thermal power station, have stated they plan to phase out coal generation by 2025, except in exceptional circumstances, and completely by 2030 .Typically regarded as 'dry year' support, the loss of coal fired thermal generation may be keenly felt in the electricity market. It remains to be seen if Genesis revise their coal generation outlook on the back of projected gas price rises.

Gas peaking capacity will increase with 100 MW currently being built (Todd Peaker) with the long-term outlook for another 360 MW (Todd Te Awamutu). Notwithstanding this, Contact has suggested it will shut its 350 MW Stratford peaker in favour of cheaper geothermal production.

Currently NZ has approximately 550 MW of wind generation capacity. The short-term outlook is for 250 MW of new wind to be built and an additional 1585 MW planned thereafter. Total wind capacity by 2025 is expected to reach 2000 MW (conservatively). 2025 projected electricity demand is expected to be 50 TWh, of which wind is expected to contribute 20%. This will make the electricity supply more volatile.

The Whirinaki 100 MW diesel generator operated by Contact Energy in Hawke's Bay typically offers its generation (peaking) into the market at the highest price in the North Island and is considered a 'generator of last resort'. As gas supply declines (and prices increase) and with increases in solar and wind, not only will we see more frequent price spikes, but higher priced gas peaking generation will be dispatched into the market.

The other available peaking technology is batteries. Batteries have been successful at providing secondary market stabilization in the South Australian electricity market with the Tesla 100 MW system installed in 2016. These systems provide frequency management services over the period of minutes. Batteries have a high purchase and fuel (electricity) price and are unlikely to cover large daily, seasonal or decadal swing in the medium term.

4.4 Other Developments

Gas supplies may still be extended compared to Figure 2. Some of the existing exploration prospects may discover gas and existing fields may be able to increase the amount of gas that can be extracted.

If gas remains an important fuel it may be imported as liquefied natural gas (LNG). Initial plans for an import terminal at Port Taranaki were developed by Genesis and Contact during the 2000s. It would of course be ironic to shut down the local gas market only to import LNG.

While the National party opposition has said it will reinstate exploration, the April 2018 decision is expected to have a quarantine effect on future exploration. This is because explorers will now see significant sovereign risk associated with investment in New Zealand. Large international oil and gas explorers require long term political support and low sovereign risk. The chance of new oil and gas exploration is very low.

These things will impact on the timing of the decline in available gas.

5. CONCLUSIONS

Gas and hydro have been the main providers of decadal, seasonal and daily swing in the New Zealand electricity market. The electricity from gas plants will be decommissioned over the next 15-20 years.

Geothermal fields may be able to produce peaking electricity and increase their field lives by not exceeding the geothermal sustainable offtake rate. Poihipi was a trial of swing production in the 1990s and it appears that other fields are being configured for swing production now. Daily swing can be used to benefit from higher prices at high demand points in the electricity market.

As the electricity system becomes more volatile due to the introduction of more "always dispatched" product (wind and solar), the need for dispatchable shoulder and peaking services, as well as their pricing, can be expected to increase.

Elevated electricity spot price spikes drive investment decisions. A future with decreasing local gas supply will push the wholesale gas price higher as demand remains tight. Gas generators will set higher electricity spot prices. As declines in gas reserves continue, the electricity market settling price will increasingly become the price set by gas generators.

Increased geothermal in the market can provide more baseload thereby leaving hydro free to perform the peaking function presently provided by gas. In a dry year scenario, the scarcity of water means hydro peaking becomes a more valuable function. This is where geothermal peaking may have potential to compete on a $/MWh basis.

GLOSSARY

FIR	Fast Instantaneous Reserve
HVDC	High Voltage Direct Current line crossing the Cook Strait
LNG	Liquified Natural Gas
MBIE	Ministry of Business Innovation and Employment
MW	Megawatt
SIR	Sustained Instantaneous Reserves
SO	System Operator (for electricity - Transpower)
WSCA	Water and Soil Conservation Act 1967

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