TRANSPOWER

The sun rises on a solar energy future

January 2019

Te Mauri Hiko

Energy Futures

Introduction

In May 2018, Transpower published the results of six months of intensive research on the future of New Zealand's electricity system. It found that New Zealand has a unique opportunity to lead the world in decarbonising its economy by replacing energy generated from fossil fuels with energy generated from renewable sources.

Meeting this ambitious target will likely require a doubling of electricity generation by 2050 to meet the needs of homes and businesses as they use electricity to drive the majority of their transport fleet and industrial heat processes.

Currently, the world is facing the prospect of unmitigated global climate change, while still hoping for advances in technology to slow this progression down.

What's particularly encouraging in the context of global climate change is that the technology to harness the power of the sun is advancing at a rapid rate, and it's expected that the price of solar technology will continue to drop to make this technology more accessible to more people. All of the *Te Mauri Hiko* scenarios incorporated large (but differing) volumes of both utility and rooftop solar into New Zealand's energy mix. Of all the elements contained in *Te Mauri Hiko,* none generated as much interest or conversation as the possibility for large-scale solar uptake in New Zealand.

There is, quite rightly, much enthusiasm for a rapidly increasing contribution from solar to New Zealand's energy future. However, there are also challenges that will require identification, understanding and then careful planning and management. Solar is a weather-dependent energy source that produces the least energy when New Zealand needs it the most, such as during the cold, dark winter months.

Based on the interest in the continually improving economics of solar energy, this paper is designed to explore an additional solar scenario for New Zealand. It is an addendum to *Te Mauri Hiko* and sits alongside additional technical work Transpower has recently conducted around battery technology and the potential electricity system implications from widespread battery adoption. It seeks to refresh solar energy's rapidly evolving context and address some of the myths which have emerged about solar in New Zealand.

Te Mauri Hiko articulated a bold energy future for New Zealand. It is a future in which New Zealand leads the world in harnessing its unique renewable energy resources to decarbonise its economy. Such is the rate at which technology is now evolving that this paper takes a closer look at the case for solar, just seven months after the original *Te Mauri Hiko* was published.

Section 1:

The case for solar in our energy future

In 2017, solar became the leading form of new utility energy generation in the world.

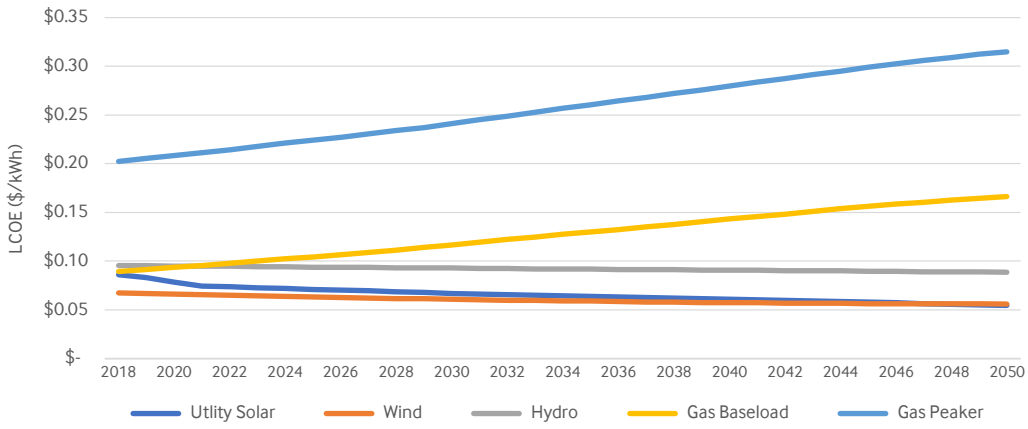
The United Nations reports that in 2017, 98GW of solar generation was installed globally, exceeding the 70GW of new fossil fuel generation built the same year by 40 per cent. This represents a significant global shift – the first time since the industrial revolution that a renewable form of energy has outstripped the construction of conventional fossil fuel-powered electricity generation.

This shift is the result of a long-running trend of falling solar prices. Prices for solar installations have been helped at times and, in certain locations, by government subsidies but, stripping out all subsidies, utility solar is now on a pricing par with gas-fired peaking power stations. (It should be noted here that this is on a per unit of energy produced basis. However, this is not a direct like-for-like comparison as gas-fired peaking power stations produce power on demand, whereas solar produces variable energy output and varies by region.)

Within the industry, looking at the real, underlying costs of energy sources is called a 'levelised cost of energy (LCOE)'.

Figure 1 below shows the levelised cost of energy for a range of electricity generation technologies[1]. With forecast carbon prices applied to gas-fired electricity generation, this graph shows that the cost of energy from gas-fired power stations will be double the price of energy from utility solar within a decade.

Figure 1: NZD cost of energy from different sources as technology and carbon prices evolve



[1] Based on the National Renewable Energy Authority: https://atb.nrel.gov/electricity/2018/summary.html

by 2050 utility solar is likely to be the world's cheapest form of energy.

The levelised cost of utility solar is expected to continue falling – by a further 24 per cent over the next 10 years, and by over 40 per cent by 2050. Based on what we currently know and believe, by 2050 utility solar is likely to be the world's cheapest form of energy – marginally cheaper than wind, which will also continue to fall in price.

The Massachusetts Institute of Technology has reported that the cost of photovoltaic solar cells has fallen by 99 per cent over the last 40 years. The installed cost per watt of solar energy has halved in Australia in the last six years.

The decreasing cost and steadily improving solar performance, as well as an increasing focus on sustainability and self-reliance, are now driving the mass adoption of distributed solar in homes and businesses, as well as grid and network connected solar farms.

Falling costs and improving technology are leading to global adoption of both distributed and utility solar.

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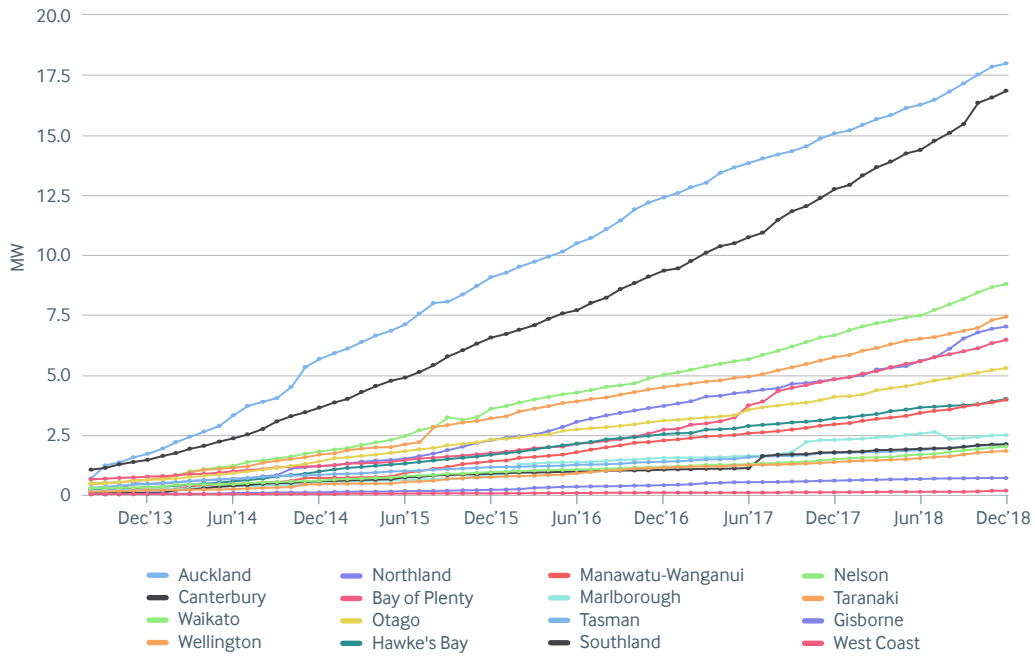
Section 2:

Solar in New Zealand

In New Zealand, solar has been slow to take off. However, with the unsubsidised cost consistently falling, this is now beginning to change.

New Zealand already has over 85 MW of distributed solar installed, almost half of which was installed over the past two years. New Zealand's installed solar prices have been falling rapidly and should continue to fall as demand continues to increase, supporting a healthy domestic solar industry in New Zealand.

Figure 2: Solar growth in different regions of NZ



Source: emi.ea.govt.nz

Section 3:

Shining a light on the myths

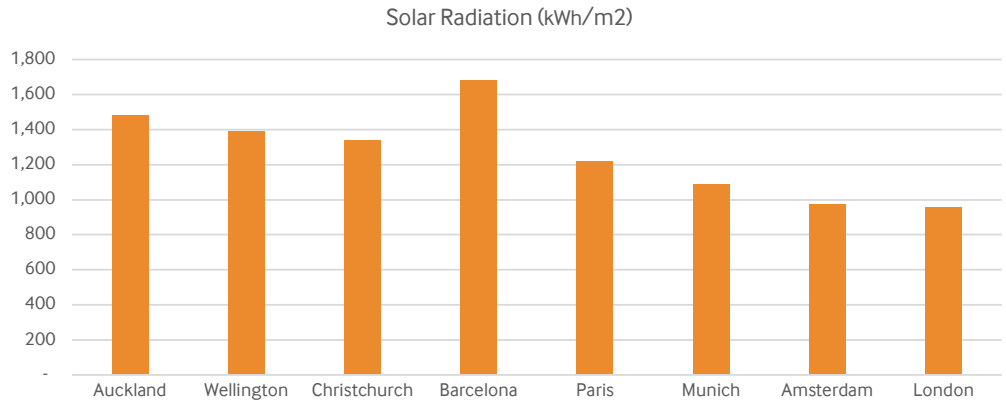
There are many myths and misconceptions about solar technology.

Much of the input and questions received about *Te Mauri Hiko* focused on this technology and the assumptions made when modelling future scenarios. We have decided to explore these in greater detail here, drawing on the best global and local sources.

Myth: *New Zealand isn't sunny enough for solar*

This is plain wrong. According to NIWA, New Zealand has an abundance of sunshine - putting many parts of New Zealand ahead of parts of the world where solar is common. Solar potential is measured through irradiance – the solar potential of a square metre of surface area. Auckland, Wellington, Christchurch and even Invercargill are sunnier than the UK, Germany and even many parts of the north of Spain. The quality and availability of the Kiwi sun is no barrier to a thriving solar energy system.

Figure 4: Comparison of New Zealand cities with other regions



While our major cities are competitive in terms of their solar resource, a number of our regions, such as Blenheim, Tauranga and Gisborne deliver even higher solar potential.

Figure 5: New Zealand's top 10 sunniest places Source: NIWA, 1981-2010)

Location	Solar Radiation (kWh/m2)	Location	Solar Radiation (kWh/m2)
Blenheim	1,519	Auckland	1,479
Tauranga	1,502	Kaitaia	1,472
New Plymouth	1,501	Nelson	1,466
Gisborne	1,498	Wanganui	1,462
Napier	1,495	Queenstown	1,455
Lake Tekapo	1,490	Rotorua	1,447

Shining a light on the myths continued

Myth: We don't have enough roof space

This is also wrong. The *Te Mauri Hiko* base case scenario suggested New Zealand could have 16GW of distributed solar installed by 2050.

Some commentators have questioned whether this is possible. The good news is it is. Today, New Zealand has 1.8 million residential households and over 300,000 business electricity connections. If they all installed embedded solar right now we could generate approximately 11 GW. Over time, the number of homes and businesses will grow with New Zealand's continuing population growth (we anticipate 2.4 million households in 2050 – a one third increase on current levels).

With the increase in homes and business premises, the solar capacity of photovoltaic cells will also significantly increase with improving technology. The combination of these effects could see the solar potential of the ubiquitous rooftop reach 27GW by 2050[2].

Myth: Our grid won't be able to handle all the distributed solar

Some have interpreted the Green Grid analysis[3] to suggest New Zealand electricity distribution networks could host at most 2GW of distributed solar before voltage constraints became a barrier.

Our recent analysis has found new technology means this isn't the case. By exploiting the natural partnership between solar and battery technology (and the utilisation of inverter capabilities), anticipated voltage constraints in electricity networks could be managed to enable networks to host 9-10GW of solar.

Inverters will be critical to enable a smart, reliable and affordable grid, but this requires the right design and standards. Every solar installation comes with an inverter – if this is well-designed and correctly set-up it can support renewable generation on the grid and reliability for households through providing ancillary services and support. New Zealand needs to stay up to date with this fast-changing technology, for example by adopting the latest global standards.

Myth: Solar will make the power system unmanageable

There are also concerns solar generation will make the power system unmanageable through grid voltage management issues and/or reduced capability in contingent event management. However, analysis shows that operationally significant solar can be well integrated with batteries. Primary analysis at 4GW of solar penetration in our battery storage paper showed no significant issues. A significant amount of energy storage and flexible generation in the form of New Zealand's hydro system provides enough capacity to manage New Zealand's evening peak demand ramp up, even with solar penetration of up to 10GW.

It is important to reinforce that, under the *Te Mauri Hiko* scenarios, electrification of the economy leads to significant overall increases in system load from multiple energy sources which further reduces solar-related challenges.

The key to successfully managing significant solar penetration across the whole of the electricity system is to have volume and coordination/reserves on batteries. Even a relatively small volume of batteries can provide an important role in providing system stability.

[2] 2018 potential assumes 4kW per household and 11kW per business, rising to 8kW per household and 25 kW per business in 2050

[3] https://ir.canterbury.ac.nz/bitstream/handle/10092/15237/UC-GG-16-C-TC-01_EEA_DG%20Hosting%20Capacity_final.pdf?sequence=2&isAllowed=y

Shining a light on the myths continued

Myth: Solar doesn't make economic sense

While this might have been true as recently as five years ago, this is now more nuanced. As we've covered elsewhere in this paper, sharply falling costs and rapidly improving technology now provide utility solar with a lower average cost compared to almost every other form of energy (except wind generation).

While utility wind is the cheapest form of renewable energy today, by 2050 solar will enjoy a slight average cost advantage over wind, based on what we know and forecast.

By way of further example, investment bank Lazard estimates new utility solar capacity can be built at a levelised cost of energy of US$36-46/MWh today. As a comparison, the cost of new gas or geothermal electricity plants is estimated to be US$41-111/MWh.

The full economics obviously depend on the site, carbon pricing assumptions and more, but utility solar is clearly an economically viable option in the mix for New Zealand's energy future. This is reinforced with New Zealand's first utility solar generation plants now starting to emerge. Mercury has a pilot site at Southdown in Auckland, and NextGen is applying for resource consents for a site to host up to 20MW in Tasman.

The economics of rooftop solar are more nuanced. The cost of energy from rooftop solar without a battery is now approaching the cost of grid-supplied electricity (a battery adds significant expense which isn't competitive yet). Without partnering rooftop solar with batteries, the electricity cannot be stored and must be used when it is generated so is best suited to businesses such as supermarkets, and hotels that use significant volumes of electricity during the day. These will likely be the early adopters over the coming years.

Figure 6 : Levelised Cost of Energy compared to generation and retail prices ($/kWh)

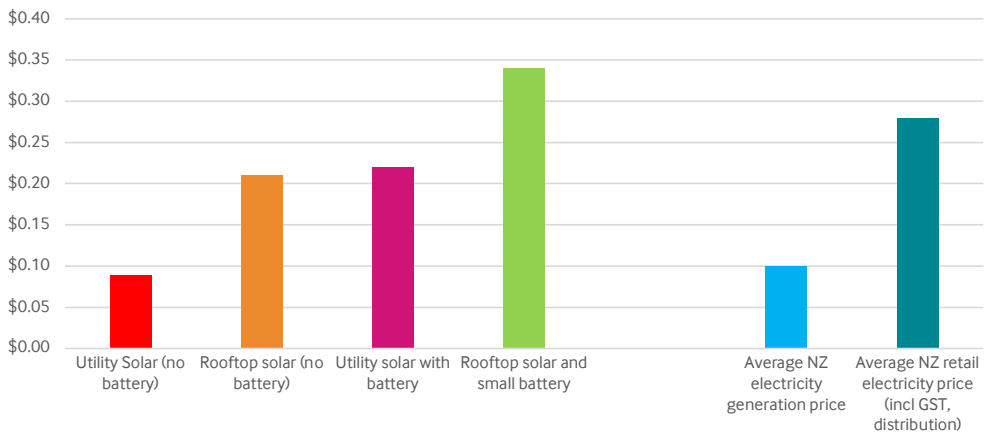


Figure 6 shows the average cost of energy produced. We compare utility and rooftop solar with and without batteries to the average New Zealand generation price and retail price. Note retail prices include the cost of distribution, transmission and retail. Without a battery, energy use must fit with times of generation. Average solar irradiation used for analysis. Generation price and retail price from Electricity Price Review First Report.

Shining a light on the myths continued

Myth: Solar can replace your grid connection

If the economics of solar can work in New Zealand, can rooftop solar panels replace your grid connection? A key aspect of the electricity grid is it enables a network of diverse energy resources to meet needs at any point in time. Achieving this level of resilience with domestic rooftop solar would currently be almost impossible.

To cover a cold and rainy winter week without a grid connection would require a significantly overbuilt rooftop solar system. Using actual solar output and demand data we estimate even with a 25 per cent drop in household demand load to minimise shortages, the average household would need a 51kW rooftop system that would likely cost over $100,000 to buy and install.

Additionally, this scenario also relies on having a fully charged electric vehicle available at home as a battery to power household applications[4]. Currently a dedicated home battery the size of that in a Nissan Leaf EV would add approximately $28,000 to the solar bill.

These scenarios highlight how complementary the national grid is with distributed solar electricity – replacing the grid is extremely expensive for households and businesses, but complementing it with domestic solar production is increasingly competitive and compelling.

Myth: Solar panels weigh too much for commercial roofs

Again, this is not true. A typical rooftop solar panel weighs around 10-20 kilograms per square meter. This is light enough for most roofs to safely support.

In fact, solar panels can protect a roof by shielding it from damage from light, bad weather and even helping regulate temperatures in the rooms below. The bigger challenge is to make sure the roof angle is suitable for solar. Given the propensity for flat roofs – commercial solar might even involve installing solar on walls as well as a roof to provide an averaged output across summer and winter.

[4] Typical household use is 18-25kWh per day and a new Nissan Leaf has a 40kWh battery.

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Section 4:

Te Mauri Hiko and what we expect

The electricity generation blend presented in Te Mauri Hiko highlights a future in which solar grows materially in New Zealand.

The falling cost of solar and improving efficiency means that all of our scenarios see a significant and rapid increase in distributed solar and the addition of a significant amount of utility solar.

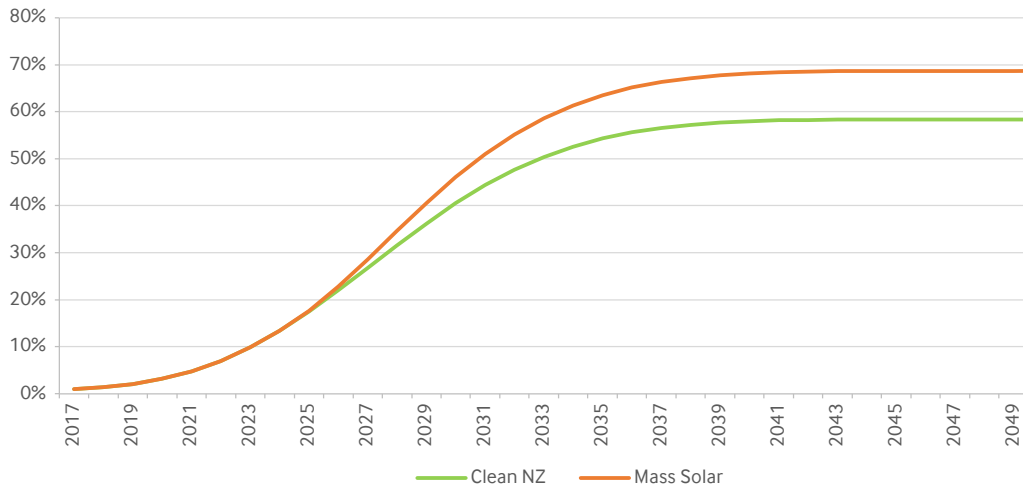
In *Te Mauri Hiko's* base case scenario, the effects of climate change continue to increase and global average temperatures rise by 1.6 degrees compared to the 1900 baseline. Large scale electrification of transport and industrial process heat requires significant new sources of generation and distributed solar becomes a material and cost-effective contributor to New Zealand's emergence as a genuinely low carbon economy. (Current concern around the implications of failing to meet the Paris Accord's 1.6 degree climate change target – for which the world is not yet on track – may yet serve to further accelerate solar adoption globally.)

“The falling cost of solar and improving efficiency means that all of our scenarios see a significant and rapid increase in distributed solar and the addition of a significant amount of utility solar.”

Under this base case scenario (Clean NZ) the number of New Zealand homes and businesses with solar panels installed rises to 1.3 million households (58 per cent) and 77,000 businesses (25 per cent of connections) by 2050. Combined with improvements in the generation potential of solar panels, distributed solar is forecast to contribute 16TWh of energy by 2050.

Te Mauri Hiko also included a 'mass solar' supply scenario, which sees considerably more distributed solar generation, driven by advances in nanotechnology. This scenario sees domestic solar installations hit 69 per cent of households and 40 per cent of businesses, providing 26TWh of electricity in 2050. The 'Big South' and 'Peakers Permitted' scenarios both used the same distributed solar assumptions as for the base case.

Figure 7: *Te Mauri Hiko* scenarios - household uptake of rooftop solar to 2050



These scenarios have been an area of significant feedback and discussion. *Te Mauri Hiko's* forecasts for solar in New Zealand are significantly above the assumptions of some others and a number of stakeholders have questioned these scenarios. We welcome this feedback and challenge – indeed this is the precise point of *Te Mauri Hiko*.

We have taken the time to reconsider the scenarios for distributed solar and have performed a detailed analysis using technology diffusion curves to extrapolate from existing uptake and adoption across the country. This analysis has confirmed that our solar base case remains feasible if distributed solar uptake continues to perform strongly and remains supported by falling prices and advances in technology. This analysis also confirms our mass solar scenario also remains possible.

However, this process has highlighted an additional scenario where rooftop solar uptake is less vigorous and caps out at around 15 per cent of households and businesses. As a result, we introduce the additional 'Roaring 40's' scenario to the *Te Mauri Hiko* mix.

"this process has highlighted an additional scenario where rooftop solar uptake is less vigorous"

Figures 8 and 9 show the impact that this reduced rooftop solar has. As electricity demand continues to grow, alternative renewable generation is needed. Some of the distributed solar is replaced by utility solar, showing the valuable role solar plays in the overall system, but much of the solar output is replaced by wind - a low cost source with stronger alignment with New Zealand's winter peak.

Figure 8: Solar generation under different *Te Mauri Hiko* supply scenarios, including 'Roaring 40's' scenario

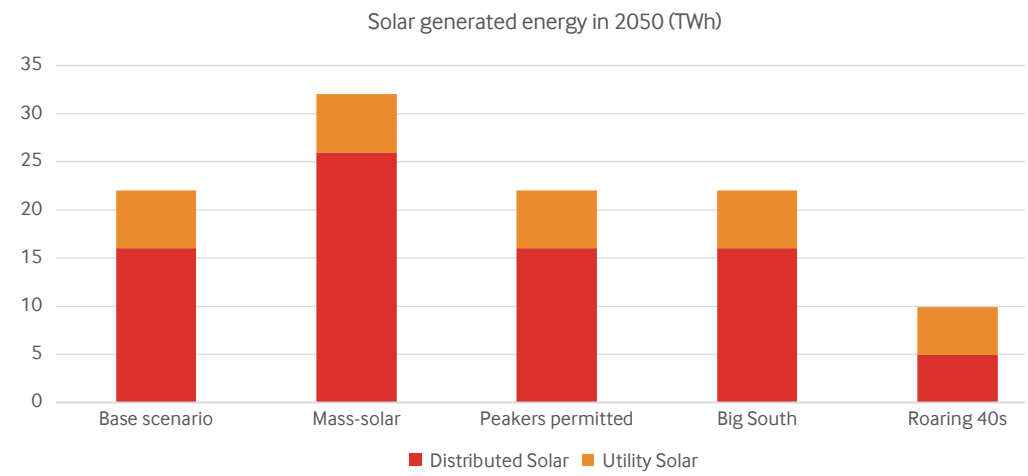
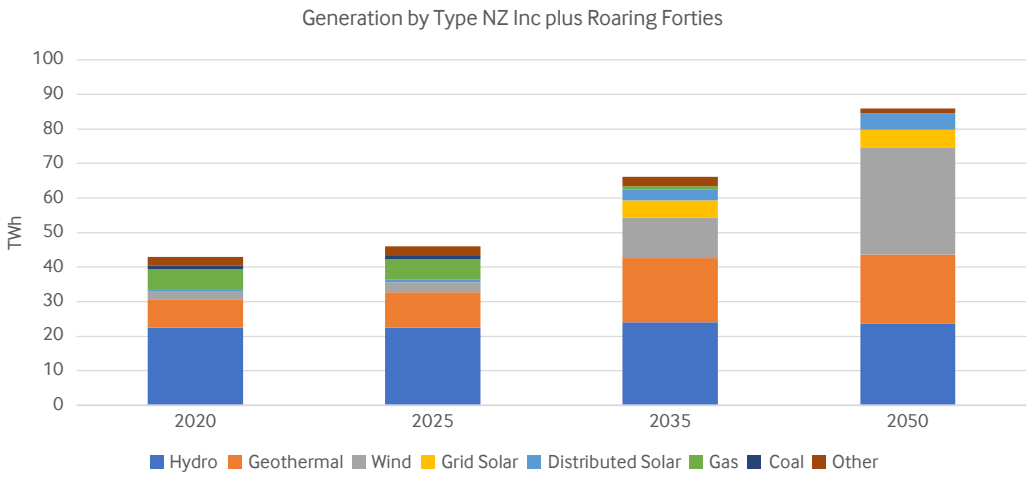


Figure 9: The new 'Roaring 40's' scenario



We continue to believe that solar has a clear role to play in New Zealand and, based on compelling cost and technology trends, tend towards the more ambitious scenarios as the most likely outcome by 2050.

As the analysis above shows, the economics of investing in solar at a utility and distributed level is now firmly in the mix of viable electricity generation technologies.

As solar continues to fall in price, this economic imperative will continue to grow. With solar in a range of locations and as part of a diversified suite of generation capacity, solar can create a more robust and reliable generation profile to support the transformation of New Zealand's energy future and economy.

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Step-change potential for solar

Solar technology continues to evolve and step-change innovations are likely. While emerging technologies can sound like the realm of science fiction, the inherent challenge for the electricity industry, for investors and for policy makers is in staying open to possibilities that might be beyond our current experience.

We should expect significant and potentially disruptive energy technology innovation over the next 30 years. While the *Te Mauri Hiko* scenarios are based on technology as we currently know it, there is the potential for solar to exceed current assumptions based on technology innovation.

By way of just a few examples, global research and development is already creating new innovations across all aspects of solar technology – some of the most interesting emerging ideas are around nano-technology, solar paint and the idea of harvesting solar energy from space.

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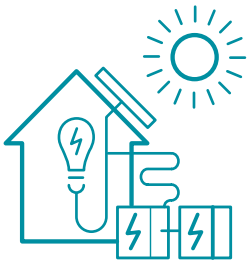
Section 4:
Implications and challenges to resolve

Te Mauri Hiko describes an energy future which would see New Zealand leading the world in cutting carbon emissions and building a low carbon economy.

Solar has a clear role to play in this energy future but we acknowledge that, like any major new technology adoption, there will be challenges to be addressed and overcome.

There are four critical issues that need to be addressed collaboratively in order to realise solar's future for New Zealand.

Aligning solar with the evening peak



New Zealand's electricity load already experiences a significant peak in the early evening when the sun goes down and lights, heaters and a range of domestic appliances are turned on.

Without energy storage, solar will amplify the challenge of meeting these peaks – further reducing the load in the day while being unavailable to assist with a sharper evening peak. To manage this challenge, the system will need battery capacity and tariff structures that enable and encourage electricity to be time-shifted from the daytime when the sun is out to the evening peak when the energy is most needed.

This could be in the form of electric vehicle batteries, home batteries, community batteries or batteries elsewhere in the grid (especially in partnership with utility solar). Each of these potential setups offers different advantages but a critical aspect of making solar work in our energy future will be ensuring that batteries are encouraged.

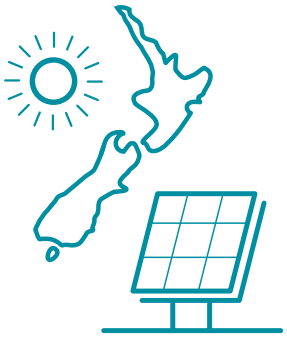
And with the winter peak

A critical component of solar is the angle of installation. In summer, the sun is higher in the sky so a flatter roof (up to a point) captures more solar radiation. In the winter, the sun tracks lower in the sky, making a different angle of solar installation preferable for maximum performance. This shift in angle is significant - for example, in Auckland the summer optimum angle is around 27° and in winter it is 52°.

We have reviewed data for existing distributed solar installations and found that this is predominantly set up for summer (likely reflecting the angle of the roofs it is installed on). If this pattern continues, then the 16TWh of solar energy we foresee in *Te Mauri Hiko* would be heavily skewed to summer (while New Zealand's energy demand continues to peak in winter).

A more balanced supply would include some higher angle installations to provide more efficient winter peaking. Simple frames above the roof to change the angle could easily and cheaply address the problem, but there may be aesthetic or consent issues to consider. Alternatively, as the cost of solar falls, options include using vertical walls that face north or the solar imbalance could be mitigated by changing the use of our hydro plants within our system to be more of a 'winter battery'.

With solar playing a bigger role in New Zealand's energy future, these issues of angle, installation design and the winter demand peak challenge will require increasing planning focus from the industry, government policy makers and a range of building and construction stakeholders. A coordinated and strategic approach to maximising this opportunity is required.



Building solar in the right places at the right times

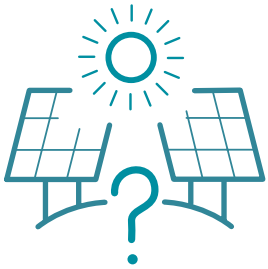
Again, consistent with the need for clear, whole-of-system planning, it will also be critical to ensure solar is added in higher value locations in a timely manner.

Higher value locations are not only places where the generation potential is high, such as the high sunshine regions of Tasman and Northland, but also places close to demand so the need for additional new transmission is reduced. It's critical network pricing structures encourage these outcomes and that the Resource Management Act supports addition of renewables, especially at the utility scale, in a timely manner.

A diversity of utility solar locations will be the best overall outcome in terms of effectively managing local weather effects and intermittency.

Managing the continuing technology evolution

Solar technology continues to evolve rapidly and the prospect of further step-change innovation breakthroughs is likely. To underpin this we need to get our standards right, including inverter standards to ensure these can enable renewables, and add reliability.



A challenge in markets with fast-changing but long-lived technologies is to balance the investment today with the ability to access tomorrow's technologies. From a New Zealand Inc. perspective, the preferred path would be for a steady and consistent stream of solar adoption over the coming years and decades that balances different technologies at different times. This approach can ensure New Zealand doesn't over-invest in an early technology that later becomes stranded or would have been significantly more effective and efficient had the investment waited.

We cannot afford to wait for the future, regardless of its promises. Investing steadily in solar while the costs continue to fall and the technology improves will ensure the advantages are shared and the benefits realised for all players. At the same time, this approach will enable us to continue to deploy the world's fastest growing source of clean electricity to the advantage of New Zealand's economy, consumers and our collective climate.

Summary

We've been upfront from the start: the scenarios in *Te Mauri Hiko* are likely to be wrong – you can count on it. There are myriad variables in New Zealand's energy future, including some we cannot envisage at this time.

Regardless, we have invested considerable effort into understanding the potential shifts in New Zealand's energy landscape and we've involved industry experts, people with deep technical knowledge and those who study the possibilities of the future in trying to better understand these issues as fully as we can.

"There's no silver bullet in the battle against unmitigated climate change or in decarbonising our economy. However, what this work shows and what we assert here is that solar energy is certain to play an increasing role in our energy future and in our efforts to avoid a climate crisis."

While we can't predict the future, we continue to have a high level of confidence in the scenarios outlined in *Te Mauri Hiko*. We are confident New Zealand faces a unique opportunity to embrace a different energy future and decarbonise our economy in the process.

The extent to which we are able to realise these opportunities lies in engaging with these possibilities now. This is the purpose of *Te Mauri Hiko* and we welcome feedback, challenge and alternative perspectives.

There's no silver bullet in the battle against unmitigated climate change or in decarbonising our economy. However, what this work shows and what we assert here is that solar energy is certain to play an increasing role in our energy future and in our efforts to avoid a climate crisis.

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