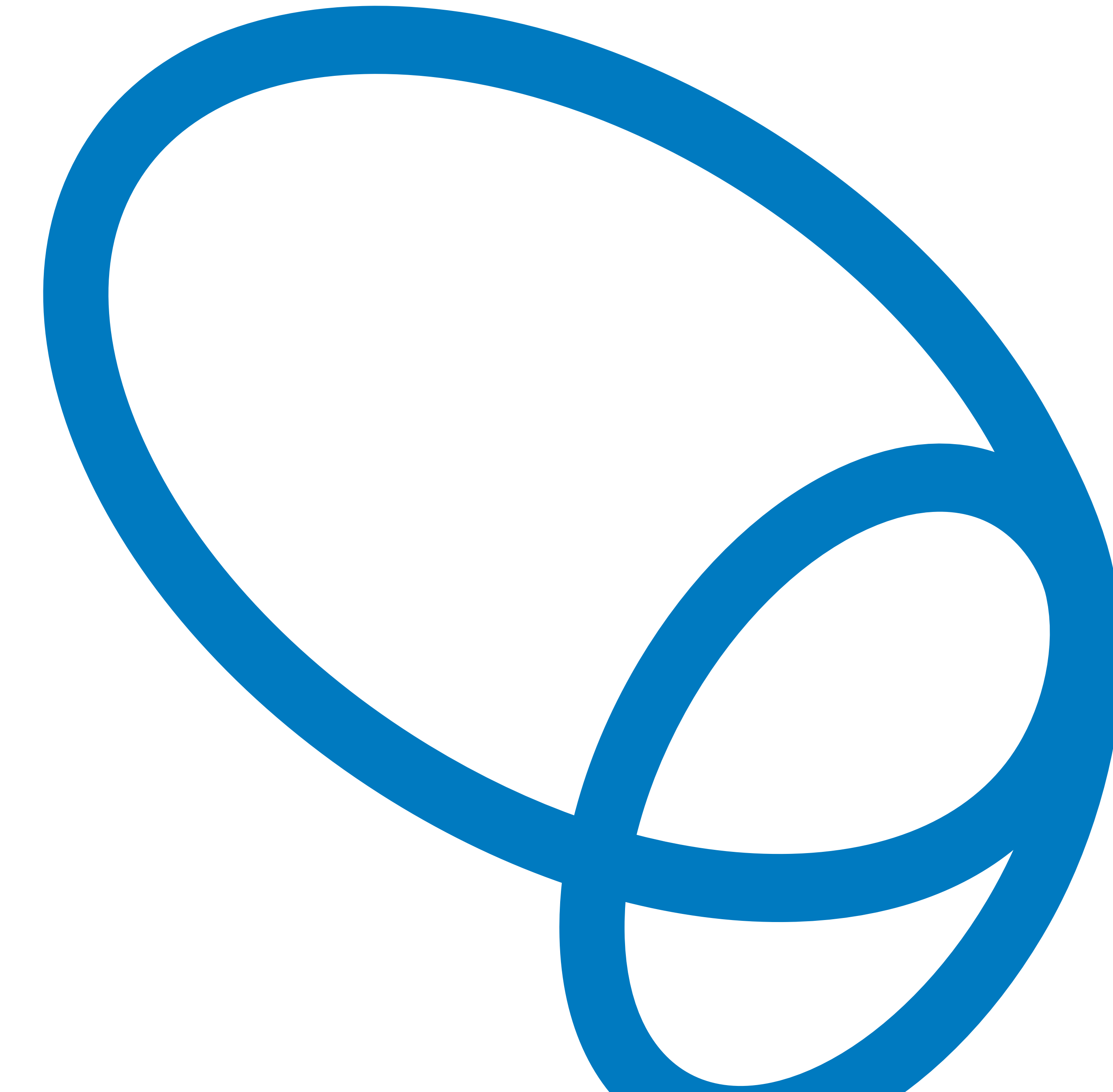
engineering new zealand
Institute of Engineering Professionals

CLEANER ENERGY

WE'RE ASKING THE HARD QUESTIONS. WE'RE SEEKING ADVICE FROM THOSE WHO ARE PASSIONATE. WE'RE EXPLORING ALL THE POSSIBILITIES. WE'RE CREATING MORE SUSTAINABLE ENVIRONMENTS. WE'RE DRIVING CHANGE WITHIN OUR INDUSTRY. WE'RE **ENGINEERING A BETTER NEW ZEALAND.**



CONTENTS

AN ENGINEERING PERSPECTIVE

This second *Engineering a Better New Zealand* looks at two areas where meaningful, well-engineered change can make a difference to our greenhouse-gas emissions and our fight against climate change: cleaner electricity and cleaner transport.[1] Action in these areas would also improve air quality and boost the health of our ecosystems.

It follows our first *Engineering a Better New Zealand* publication in August 2018, which voiced engineers' responses to two other challenges keeping them awake at night: seismic resilience and water. That publication called for engineers, the community and government to work together to take action. It called for us all to value, cost and build resilience into our critical systems and infrastructure.

Engineers work at the heart of all New Zealand's infrastructure, processes and systems. This gives us a responsibility to take a leadership role, using that unique perspective to resolve challenges and take opportunities to innovate. Our response to the massive challenges of climate change, our primary focus in this publication, comes from our experience designing practical, innovative solutions and helping bring these solutions to life in partnership with our clients, communities and policy makers.

Engineering a Better New Zealand: Cleaner Energy sits in a context of many other climate change reports, international obligations, global conferences, research, commissions and initiatives. It represents New Zealand engineering experts' view on what would make the most difference for our country and what engineers can contribute. While industrial processes are another significant factor, in this publication we focus on cleaner electricity and cleaner transport. The challenges we're facing in these areas need action at every level: individual, community, national and global.

Our consideration of cleaner energy reveals themes that resonate with our initial *Engineering a Better New Zealand* report. First, how critical it is for all players, including engineers, to look wider than their speciality or field of interest and understand the interactions that make up these complex systems. A huge range of engineering expertise is at play in the electricity and transport sectors, from electrical engineers specialising in different sources of power or the grid itself, and chemical and process engineers, to engineers who design transport systems, experts in particular fuels and engineers who design the services and products that use that energy. Do we have the right engineering expertise in place at all parts of the system?

Second, the importance of long-term thinking that values resilience and sustainability. This kind of thinking means making bold and brave decisions, frequently without certainty about the future but with a clear eye to evidence-based trends. It takes a longer-term view of the tension between energy supply and demand, balancing immediate needs against the risk posed by climate change and the deterioration of air and ecosystem health.

Part One of *Engineering a Better New Zealand: Cleaner Energy* sets out our vision for more renewable and more resilient electricity and includes how this interconnects with our transport needs.

Part Two considers cleaner electricity more closely. It asks where our electricity comes from, how are we using it, and what needs to change? Can we minimise New Zealand's greenhouse-gas emissions from electricity production? What changes do we need in terms of supply – and how might we engineer supply to meet changing future demand? We also consider how we can create a more resilient balance of supply and demand in a renewable system.

Part Three examines our transport network, which is our fastest growing source of greenhouse-gas emissions. Bearing in mind what we've learned about electricity supply and demand, is electrification of transport the answer? How can our transport system be shaped to deliver cleaner and better outcomes for New Zealanders?

PART 1

OUR VISION

WHAT WILL CLEANER ELECTRICITY AND TRANSPORT LOOK LIKE?

OUR VISION FOR A SUSTAINABLE NEW ZEALAND

The Government has set targets for New Zealand to deliver on our international obligations and ensure a climate-resilient future for New Zealanders.[2] What does this low-emissions picture look like through engineers' eyes?

In our vision, New Zealand's electricity and transport systems work in tandem to create a sustainable future. Engineering experts in all parts of the system work together with clients, communities and government to make this future a reality. They put the infrastructure, networks and technology in place so that it's easy for people to make the right decisions about energy use.

Almost 100 percent of our electricity comes from renewable sources

New Zealand makes greater use of wind, solar and other renewable sources so that close to 100 percent of our electricity is renewable. Successive governments create a climate of innovation, with new, sustainable technologies enjoying an attractive return on investment. If non-renewable sources are used, their costs to society or the environment are effectively priced in, removing its unfair advantage in the marketplace.

Resilience isn't sacrificed for renewability

It's much easier to be renewable if you don't think about resilience. In our vision, New Zealand avoids that trap, and our renewable system is hedged against seasonal or weather influences. Long, dry winters that drain hydro lakes don't cause power crises and calm days don't cause outages, even if both these things happen at the same time. Our mix of sources is well planned.

When electricity is plentiful, we hold it through better forms of storage, then release it back into the grid at times of high demand or low supply. We create a more sophisticated approach to the management of supply and demand through a smart grid, distributed sources of generation and storage. Outages are rare.

Engineers take a systems approach in designing this future

This means considering how all sources of supply and demand interact, and what this means for the entire system. We work collaboratively with investors and regulators to create an energy system that serves all New Zealanders, rather than focus on individual pieces of the puzzle. Sophisticated computer modelling means we can reject in advance strategies that won't work and optimise those that will.

"New Zealand plans for tomorrow, not an extension of the past."

Nearly all land transport is electrified – and the rest runs on transitional, alternative fuels

Electric vehicles are ubiquitous. Those that aren't electric, often heavy vehicles, run on biofuel or hydrogen produced with renewable energy. And these heavy vehicles are potentially transitioning to electricity as battery technology, infrastructure and disposal improves. At the same time, freight is shifting from roads to rail, which is electrified or fuelled by hydrogen, and supported by adequate government funding.

The way we fuel transport is the least of what's changed

Our future includes a better transport system that moves people quickly and cheaply, while minimising greenhouse-gas emissions.

The private car is no longer king in urban areas. City dwellers see transport as a cheap, on-demand service, rather than an expensive and depreciating individual asset that spends most of its time stationary. Smart applications make car-sharing easy and efficient, removing the hassle of parking. Scooter- and bike-sharing for short journeys flourish. Cities have reliable mass transit and are planning for a potential autonomous vehicle future.

As a result, our urban centres look totally different and feel much more liveable. Space previously used for storing cars is freed up for pedestrians, outdoor living and activity, and non-vehicle infrastructure.

We create the right incentives

The right incentives create this shift. New Zealand plans for tomorrow, not an extension of the past. Regulators, planners and engineers work together to predict technology shifts and consumer behaviour, then make it easy for people to choose cleaner, more efficient transport. Individuals and companies also drive the change by getting on with creating solutions, because they want to play their part in creating a more sustainable future: economically, socially and environmentally.

The change also happens because engineers ask, "what if?". What if autonomous vehicles become a widespread reality? What if drones eventually become commuter transport? What if we could remove freight from our roads? Asking visionary questions means we embrace this future with both hands.

HOW DO WE GET THERE?

Our recommendations

1

Increase energy storage so we can use more renewable electricity

Relying more on renewables means making sure we can still meet demand in the dark of winter. Our historic approach has been central planning or letting the market sort itself out. But if we increase renewables, we need more storage to ensure supply. This means a concentrated, joint effort to solve the seasonal imbalance, including exploring pumped storage of water at scale, batteries, solar thermal and hydrogen.

2

Refocus our electricity market to incentivise renewables and new technologies

Our current market is structured around hydro power stations and thermal units. Let's expand our focus and review market rules to cater better for wind and other renewables. This means promoting storage and arbitrage to complement wind generation, so that New Zealand makes the most of our ample resource. It means better coordination between generators, with a whole-of-New-Zealand approach to managing supply. Some combinations of renewable sources provide better resilience together; for example, wind and solar, and we need to manage and incentivise this at scale.

3

Future-proof our physical distribution network so it's less vulnerable to climate change and storms

We need to deliberately plan for next-generation power consumption and generation in the distribution network. This means enabling low-cost, microgrid-enabled connections and increased resilience. It means incentivising the development of distributed supply and grids that integrate with smart appliances, more effectively balancing supply and demand. Future-proofing also means taking a hard look at the benefits of undergrounding, especially in the context of increased storm activity and coastal sea-level threats generated by climate change.

4

Grow our engineering capability at the cutting edge

We need more engineers with the right experience to take advantage of technological advances, especially in terms of renewable sources like solar, tidal and wave. This means recognising and investing in these emerging and niche fields, through our engineering schools and accreditation processes. It also means giving Kiwi engineers the chance to gain new skills and experience, in offshore projects and also at home, as well as making sure we attract these kinds of engineers to New Zealand.

5

Put the right price on carbon

The government can tilt the playing field away from traditional and accessible carbon-generating sources like coal towards cleaner technology, if it creates the right price for carbon. The right price creates a new market that will help us invest in the skills and technology New Zealand needs.

6

Drive down demand across our urban road networks, reducing congestion and emissions

Regulators should introduce digitally enabled variable road pricing that reflects the real costs of peak demand, so that drivers shift to other modes, including sharing. And then apply the same model to parking, at the same time reducing space dedicated to parking in cities. Driving down demand for rush-hour roads and parking means regulators making brave decisions and lifting their gaze to medium- and long-term horizons.

7

Prioritise next-generation mass transit, without polarising the community

Let's make space for mass rapid transit along development corridors in urban centres and consider the feasibility of light rail, road trams and, where appropriate, heavy rail. But, crucially, we need to avoid the politicisation of transport projects by holding to a clear vision if we want to deliver the best results for New Zealand. The traffic, road, and civil engineers and traffic planners have to be given objectives and allowed to propose the best way forward together.

8

Engineer an urban transport system that's greater than the sum of its parts

Our future transport system will deliver transport as a service. It will leverage information systems to provide reliable, fast, and stress-free end-to-end trips that integrate public transport with car share and other modes, including a potential autonomous-vehicle future. This means public investment in other modes (and information systems), including public transport, and allowing transport planners and engineers to create the systems that knit modes together.

9

Pursue alternative fuels as well as electrification

We need to take biofuel and hydrogen seriously as an option, particularly for heavy vehicles. As other cleaner energy technologies emerge, we need to be ready to assess these for their benefit to New Zealand and against our objective of reducing our carbon footprint.

10

Make our road corridors more resilient

Sea-level rise will expose us to increasing threats from king tides, storm surges and tsunami. We must engineer every possible opportunity to re-route transport inland away from low-lying coastal land. Our seismically prone cities also need back-up transport lifelines.

PART 2
CLEANING UP ELECTRICITY

HOW DO WE MAKE OUR ELECTRICITY SUPPLY BOTH CLEANER AND MORE RESILIENT?

CLEANING UP ELECTRICITY

New Zealand's proportion of renewable electricity already stacks up well internationally – but we can do more. While nearly half of our greenhouse-gas emissions come from agriculture, those from energy production are next highest. They present a challenge that engineers can rise to.

But how do we balance supply and demand, deliver cleaner electricity, design greater energy-use efficiency *and* ensure reliability? This question sits at the heart of our cleaner-electricity challenge. For example, we could build more solar generation only to find that without better battery technology, energy produced in the heat of the day is wasted and we struggle to heat our homes in winter's short daylight hours.

To be cleaner, we need to refine our existing sources of supply

In 2017, hydro, geothermal and wind together supplied 82 percent of New Zealand's electricity.[3] To boost our proportion of renewables, and get closer to the Government's 100 percent target, we need to take advantage of new technologies and incentivise cleaner sources of supply.

Hydro will remain the backbone of our electricity system, even though the negative ecological consequences make new large-scale projects unlikely. But there are opportunities to engineer more efficiency into existing hydro schemes while mitigating their impact on natural water systems. New micro schemes with smaller ecological footprints also have the potential to increase hydro supply.

Wind makes up 5 percent of generation today but our windy land can generate much more power. We don't need to look offshore to find sufficient space or wind, unlike other countries. Newer turbines generate at lower wind speeds, which makes the electricity they generate cheaper. While the fundamental design of turbines isn't changing, blade sizes keep growing, with the latest commercially available onshore models having blade diameters of around 160 metres and capacity of nearly 5 MW. These advances bring efficiency but require increasingly sophisticated civil engineering works.

Geothermal resources generate 15 percent of our electricity. New plants coming on stream in the Waikato could boost this proportion, as could increasing efficiency of geothermal generation by using excess heat to produce steam or hot water. But geothermal energy isn't strictly renewable, coming from a finite source, and it emits carbon dioxide and methane.[4]

The solar contribution to our electricity supply is minute. But rapid improvements in technology mean it shouldn't be discounted as a potential future source of supply, especially if the environmental impact of its production and disposal can be reduced. New materials like perovskite mean the next generation of solar photovoltaic technologies will be much cheaper and more efficient, while improvements in wind generation, for example, will be more incremental. We could see solar glass and solar paints transforming the solar-generation landscape.

Another way of harnessing the sun is solar thermal technology, which captures the sun's heat and stores it for heating or to generate electricity. For example, some salt mixtures melt at 200°C and can be used in this form to store energy from the sun. Up till now, solar thermal has been overshadowed by the rapid cost reduction in large-scale solar photovoltaics. But solar thermal's built-in energy storage will become more valuable as the national grid increasingly draws from inherently variable renewable sources.

Demand is the flip side of supply

New Zealand's electricity demand has been relatively flat for the past few years. It's always possible we won't return to the steady demand growth of the past. But engineers predict that the make-up of today's demand will change dramatically tomorrow as we move toward carbon neutrality.

New technologies, from electric vehicles to streaming, are shifting and potentially expanding our patterns of electricity use. At the moment, under 2 percent of new vehicles in New Zealand are electric.[5] But if we continue to incentivise uptake and electric vehicle technology becomes cheaper, the growth of this carbon-friendly fleet will significantly increase electricity demand.[6]

That's without considering electrification of other transport, such as rail and freight, in the service of our carbon targets. The Government's October 2018 decision to retain and refurbish electric locomotives on the North Island Main Trunk Line is a step towards a cleaner rail future. New electric or hydrogen-fuelled locomotives, and dual-mode locomotives, would be another advance.

Electrifying more industrial processes, as we look to reduce their dependence on fossil-fuel energy, would also drive demand for electricity. But demand generated through new uses of electricity can be somewhat offset by improvements in energy efficiency, especially if we make it easy for people to choose the most energy-efficient alternative when they replace an appliance or renovate a house, for example.

Matchmaking future supply and demand

As we deliberately increase our dependence on renewables, we must engineer their supply to match peaks in demand. New Zealand's demand doesn't naturally suit our supply. In cold, dry winters, our hydro supply falls at the same time as seasonal demand for heating peaks. And our hydro lakes can only hold about six weeks' of electricity-generating water.

Similarly, domestic solar panels provide power at home during sunny days when it's least needed. They also face seasonal limitations, especially in the deep South, where winter sunlight hours are short. But solar panels on public, commercial or industrial buildings can power their day-time demand for air conditioning, lighting or technology. In the future, we could be building their windows and roofs from solar-panel material. And plugging our electric vehicles in to charge in the car park below. New Zealand currently lacks experienced engineers at the cutting edge of solar technology, so we would need to grow our capability if we're going to take full advantage of this potential supply.

Wind, on the other hand, blows hardest when seasonal demand is highest. Wind's advantages can complement the limitations of hydro power generation. Without careful planning, adding more wind generation capacity can have an adverse effect on the energy market by flooding it with cheap power when wind is plentiful. This depresses the spot price, making wind less attractive to new investors. Too much supply leads to wind spill, where generation is switched off if the price is below, for example, $15/MWh. New Zealand already has a number of consented wind farms waiting for viable market conditions before they are built.

Cheap wind power could incentivise development of storage or demand management technologies uniquely suited to New Zealand's situation, but only if market conditions or the right incentives are in place. Alternatively, abundant wind resource in areas like the lower North Island could generate hydrogen as an alternative fuel source.

Matching supply and demand means factoring in these economic realities. Wind and geothermal generation are our cheapest options for adding capacity. But new wind projects will only be funded if investors predict a return. And while geothermal is attractive in terms of cost, it taps into a limited energy source and creates greenhouse-gas emissions. Other technologies, like tidal or wave power, remain uneconomic in the foreseeable future but our systems still need to factor in their future possibilities. Tidal power has the potential to deliver renewable electricity unaffected by weather, rainfall, or time of year, if the technology can be sufficiently scaled up.

New technologies can manipulate supply and demand

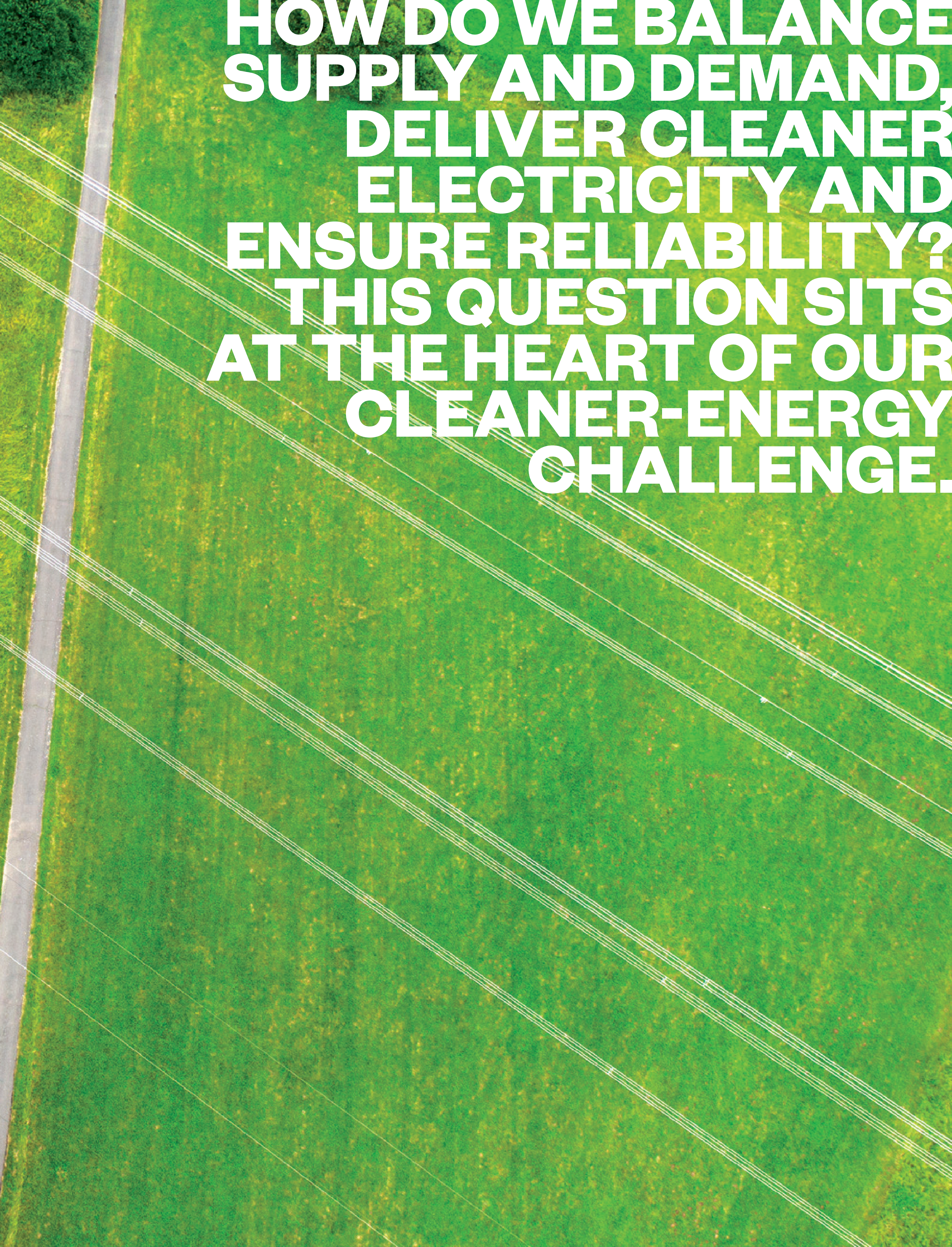
If we can better store water through pumped storage, our hydro supply won't be so vulnerable to dry periods. Dams give us a few weeks' storage[7] but this isn't enough to weather long dry spells, especially as our climate changes. Pumped storage involves pumping water from a low-level reservoir to one that's at a higher elevation. The pumps are turned on when supply is plentiful and power is cheap. When the stored water is released, during times of high demand, it flows down through turbines and generates electricity.

Because pumped storage can re-use existing reservoirs, ecological consequences are minimised.

Batteries also store electricity, helping us better take advantage of variable renewable energy sources. Grid-tied batteries, which are capable of both storing energy and feeding it back into the grid, help balance supply and demand. Battery disposal still poses problems, with recycling of Lithium Ion batteries currently in its infancy. And as we build batteries big enough to power buses, trucks or ships, can these be repurposed to support the grid once they've lost capacity to electrify transport?

A smart grid would detect and react to changes in supply and demand, using digital communications technology. Smart meters can adjust prices according to the availability of clean energy, potentially driving consumer behaviour: a smart grid would take this a step further. For example, automatically turning on smart appliances when supply is plentiful, rather than all the dishwashers in New Zealand running every evening. A smart grid can integrate with distributed generation from different sources.

Virtual power plants could help by aggregating small-scale generation from a variety of sources, including domestic electric vehicles or solar panels, and feeding it back into the grid. For example, to cover a sudden generation need, a virtual power plant could tell your fridge freezer to take a brief break and your electric vehicle battery to join with thousands of others in feeding energy back into the grid. Virtual power plants overcome the fact that our distribution network was designed to supply power from the transmission network to homes, not the other way around. It's a bit like applying the Uber model to the power network. When integrated with load management (including electric vehicle charging) and household batteries, virtual power plants enable significant increases in local, distributed generation to meet urban energy needs.



HOW DO WE BALANCE SUPPLY AND DEMAND, DELIVER CLEANER ELECTRICITY AND ENSURE RELIABILITY? THIS QUESTION SITS AT THE HEART OF OUR CLEANER-ENERGY CHALLENGE.

We must build in resilience

As we shift towards more renewables, we must engineer a greater level of resilience into our energy system, so we don't inadvertently create a network vulnerable to failure. Renewable sources, which fluctuate with sunshine or wind levels, are less dependable than dense, easily transported fossil fuels.

Engineers want to join the dots between policy, regulation, demand and supply. This means reimagining the relationship between household and grid supply to include micro and distributed networks linked to the national grid. It means our neighbourhoods aren't reliant on single cables or connections and we can seamlessly deal with a sudden reduction in supply. It also means designing interdependent energy systems that harness different sources of generation. New practices and standards will be required to capture these innovations and develop the skills to implement them.

Putting generation closer to our biggest sources of demand can also help resilience. As can locating big consumers like data centres near large sources of renewable supply. Geothermal and gas sources are closer than hydro dams to our urban markets, which reduces the energy lost in transmission and lessens vulnerability to transmission line outages.

As well as a mix of generation sources, resilience relies on redundancy. This means enough excess capacity to deal with outages or unexpected weather events. What if all New Zealanders switched to electric vehicles and a cyclone cut power for three days? At the moment, our electricity market doesn't reward excess capacity unless it's used. Excess hydro capacity might mean sometimes needing to spill water during storm events. Our regulatory settings need to incentivise capacity for a metaphorical rainy day.

And resilience means making electricity's physical infrastructure more robust through physical protection or redundancy. We can expect more storm events as climate change unfolds. Lines and cables are vulnerable to trees falling in storms,[8] for example. Putting lines underground reduces this risk and protects people from the hazard. It makes most sense in less flood-prone and less seismically active areas, like higher parts of Auckland. New approaches to undergrounding and utility management developed to serve changing electricity use are likely to make undergrounding more cost effective.

Photo: Top Energy

CASE STUDY
NGAWHA EXPANSION PROJECT

Top Energy is expanding its Ngawha Geothermal Power Station, which taps into a geothermal field about 5km east of Kaikohe.

When the expansion project is completed in 2021, Ngawha will produce 53 MW or 1 percent of New Zealand's supply. A proposed second stage of expansion could increase that to 81 MW, enough to make the Far North energy sufficient. Currently, the Far North, and Northland as a whole, rely heavily on electricity from further south that's transmitted through Auckland, making it vulnerable to outages and price spikes.

CASE STUDY
SMARTER ELECTRIC VEHICLE CHARGING

Christchurch company Evnex is designing electric vehicle chargers that respond to changing spot prices.

Instead of coming home and plugging your electric vehicle into the grid during the pricy evening peak, you'll plug it into a smart charger that avoids price peaks and draws power only during periods of low demand; for example, overnight. The brainchild of electrical engineer Edward Harvey, Evnex aims to design charging solutions that avoid unnecessary investment in our electricity networks as the electric vehicle fleet grows.

Recommendations for cleaning up electricity

1

Increase energy storage so we can use more renewable electricity

Relying more on renewables means making sure we can still meet demand in the dark of winter. Our historic approach has been central planning or letting the market sort itself out. But if we increase renewables, we need more storage to ensure supply. This means a concentrated, joint effort to solve the seasonal imbalance, including exploring pumped storage of water at scale, batteries, solar thermal and hydrogen.

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Our current market is structured around hydro power stations and thermal units. Let's expand our focus and review market rules to cater better for wind and other renewables. This means promoting storage and arbitrage to complement wind generation, so that New Zealand makes the most of our ample resource. It means better coordination between generators, with a whole-of-New-Zealand approach to managing supply. Some combinations of renewable sources provide better resilience together; for example, wind and solar, and we need to manage and incentivise this at scale.

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Future-proof our physical distribution network so it's less vulnerable to climate change and storms

We need to deliberately plan for next-generation power consumption and generation in the distribution network. This means enabling low-cost, microgrid-enabled connections and increased resilience. It means incentivising the development of distributed supply and grids that integrate with smart appliances, more effectively balancing supply and demand. Future-proofing also means taking a hard look at the benefits of undergrounding, especially in the context of increased storm activity and coastal sea-level threats generated by climate change.

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Grow our engineering capability at the cutting edge

We need more engineers with the right experience to take advantage of technological advances, especially in terms of renewable sources like solar, tidal and wave. This means recognising and investing in these emerging and niche fields, through our engineering schools and accreditation processes. It also means giving Kiwi engineers the chance to gain new skills and experience, in offshore projects and also at home, as well as making sure we attract these kinds of engineers to New Zealand.

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Put the right price on carbon

The government can tilt the playing field away from traditional and accessible carbon-generating sources like coal towards cleaner technology, if it creates the right price for carbon. The right price creates a new market that will help us invest in the skills and technology New Zealand needs.

PART 3

A CLEANER TRANSPORT SYSTEM

HOW CAN NEW ZEALANDERS TRAVEL MORE EFFICIENTLY AND CLEANLY?

A CLEANER TRANSPORT SYSTEM

Transport accounts for 18 percent of New Zealand's greenhouse-gas emissions and it's our fastest growing source.[9] Changing how we fuel our transport will help meet our climate change targets. It's where engineers can make an enormous difference to climate change, with associated air quality and ecosystem benefits.

A cleaner transport system reduces greenhouse-gases in other ways, with fewer vehicles sitting in traffic for less time. By shifting people and goods around more efficiently, it boosts our economy and frees up our time.

Why transport matters from a clean-energy perspective

New Zealanders drive a lot. People lack credible public transport alternatives, and our freight runs more on roads than rail. Nearly all our vehicles run on fossil fuels and their fuel economy is poor, compared to other countries' fleets. We hold onto our cars for longer and many cars in our fleet do not have the higher emission-control standards of other countries.

But New Zealand's road network is also a key lifeline in our seismically active country. Many of our state highways are close to the coast, making them vulnerable to storms and sea-level rise. In a changing climate, heavier rainfall leads to more frequent landslips. Roading projects like Transmission Gully might have a relatively low economic cost-benefit ratio but create necessary redundancy for Wellington. So resilience must be part of the transport decision-making mix.

Electric vehicles have a downside

Electric vehicles reduce emissions, suit urban environments and cost commuters less to run. As choice and range expand, and costs drop, adoption will grow exponentially. The same can be said for other potential non-fossil-fuel sources. But these vehicles create traffic in the same way as any other car. With each trip costing less and advanced autopilots reducing driver effort, electric vehicle trips will become effortless. More electric vehicle trips mean more congestion, which in turn will need management, both in our towns and cities and on our state highway network.

Light rail rapid transit is being introduced in Auckland and considered in Wellington because it has greater passenger capacity on the same road space than bus rapid transit, and much greater capacity than cars. Light rail has all the benefits of being fully electric, without the congestion downside.

More electric vehicles will also mean more electricity demand, as discussed in Part One, and a requirement to manage end-of-life batteries. New Zealand needs a transport strategy that factors in and manages these consequences – and looks ahead to non-fossil-fuel vehicles, autonomous vehicles and their impact on the traffic system.

Battery electric buses are operating in New Zealand at the moment, with more on the way. As well as using as much green power as the grid can provide, these vehicles emit zero particulates and reduce noise pollution for pedestrians, changing the urban environment.

And electricity isn't the only answer

Biofuels can help transition long-haul transport to cleaner energy. They release less net carbon dioxide than fossil fuels and can be used in most existing diesel engines. New Zealand could grow the crops that become biofuels in areas like Northland, the East Coast and central North Island, and then locate conversion plants nearby. For example, biofuels could be refined at Marsden Point. Animal by-products, like tallow, can also be made into fuel. Engineers can design a viable system for biofuel production, starting with the suitability of different conversion technologies, while mitigating its environmental impact.

Hydrogen is another potential fuel, especially for larger trucks and cars on longer trips outside urban areas. With a range of 500km, these vehicles store hydrogen in high-pressure tanks.

Should dirty cars be on the road?

Using the stick of emissions standards could speed up the renewal of our vehicle fleet. Studies suggest emissions standards for vehicles entering New Zealand's fleet are among the most cost-effective measures to reduce emissions.[10] But replacing functional older vehicles with other current technology petrol or diesel vehicles can be counterproductive, if you factor in the energy that's already been used to manufacture them. The Climate Change Commission could play a role in setting the standards for transport emissions, as part of its work in fixing carbon budgets. For the environment's sake, this means taking a life cycle approach that factors in the scrapping of existing inefficient fossil-fuel vehicles.

Mode shift matters most

Getting out of our individual cars matters more than how we power them. Mass transit remains the fastest and cheapest way to transport large numbers of people between common urban destinations, especially as our cities grow.

Autonomous vehicles will provide a valuable connection to mass transit for the "first or last kilometre" of many journeys. For shorter journeys, new modes like the electric bike and scooter are becoming viable alternatives. But for rural areas, the car will still play a vital role, alongside the transition to electric vehicles.

Smart road pricing could help drive urban change. In Singapore, road toll charges vary in real time according to the level of congestion. New Zealand's current flat petrol taxes do not target congestion nor include electric vehicles. Reducing parking is another proven method of suppressing demand.

Where people live matters too. “Transit-oriented development”, with people living close to mass transit stations reduces commuting time and costs. Engineers play a critical role here in supporting city planning and building – get this right and we create more efficient transport systems that are easier to access and more likely to be used.

But sharing could change everything

Car-sharing apps and autonomous vehicles could dramatically reduce the need for individually owned and expensive private vehicles. If we move away from individual car ownership to shared ownership models, our cityscape will probably change. Our cities are designed around the movement of cars, with around a quarter of urban space dedicated to parking.[11] Engineers designing future transport systems must factor in this potential shift, which creates an opportunity for cities to reallocate parking space to other public uses. Increasing pedestrianisation of cities is one example of this trend. At the same time, engineers need to factor in other potential shifts, like autonomous vehicles and drones playing significant roles in transporting people and goods. Our systems and cities must be flexible enough to accommodate multiple futures.

Recommendations for our transport system

1

Drive down demand across our urban road networks, reducing congestion and emissions

Regulators should introduce digitally enabled variable road pricing that reflects the real costs of peak demand, so that drivers shift to other modes, including sharing. And then apply the same model to parking, at the same time reducing space dedicated to parking in cities. Driving down demand for rush-hour roads and parking means regulators making brave decisions and lifting their gaze to medium- and long-term horizons.

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Prioritise next-generation mass transit, without polarising the community

Let's make space for mass rapid transit along development corridors in urban centres and consider the feasibility of light rail, road trams and, where appropriate, heavy rail. But, crucially, we need to avoid the politicisation of transport projects by holding to a clear vision if we want to deliver the best results for New Zealand. The traffic, road, and civil engineers and traffic planners have to be given objectives and allowed to propose the best way forward together.

3

Engineer an urban transport system that's greater than the sum of its parts

Our future transport system will deliver transport as a service. It will leverage information systems to provide reliable, fast, and stress-free end-to-end trips that integrate public transport with car share and other modes, including a potential autonomous-vehicle future. This means public investment in other modes (and information systems), including public transport, and allowing transport planners and engineers to create the systems that knit modes together.

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Pursue alternative fuels as well as electrification

We need to take biofuel and hydrogen seriously as an option, particularly for heavy vehicles. As other cleaner energy technologies emerge, we need to be ready to assess these for their benefit to New Zealand and against our objective of reducing our carbon footprint.

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Make our road corridors more resilient

Sea-level rise will expose us to increasing threats from king tides, storm surges and tsunami. We must engineer every possible opportunity to re-route transport inland away from low-lying coastal land. Our seismically prone cities also need back-up transport lifelines.

LOOKING FORWARD

For New Zealand to play our part in driving down greenhouse-gas emissions, we must refine our sources of electricity and future-proof our transport system.

The case for a cleaner energy future is clear, particularly if we are to meet our international obligations. And it's essential if we're to remain competitive in the low-emissions world economy of the future and avoid stranded assets. Now's the time to create, develop, analyse, synthesise, and test solutions. And now's the time to accelerate our transition and be ready to implement new technology as we develop or acquire it.

New Zealand's engineers have designed world-leading hydro and geothermal energy systems. Our engineers now need to design tomorrow's low-emission energy systems for a future where sources of supply and demand are driven by technologies we can barely imagine. They will also play a key part in designing the infrastructure (both physical and digital) that supports it.

But we need the right mix of skills for this job. New Zealand needs both more specialist and more generalist engineers, if we are to design an energy and transport future that fits our unique supply and demand context. Engineers also have a responsibility to look outside their own speciality and area of interest and take systems and leadership roles. Engineers are very good at focussing on practical action, which will always be important. But to meet this challenge requires a system-wide view that understands how policy settings and technology advances can interact.

If we engineer this future well, we will create viable cleaner energy solutions and make it easy for consumers to choose the right option. Instead of asking New Zealanders to change their behaviour, our systems and technologies can help us make the right choices – the obvious and smart choices. Together – engineers, policy makers and our communities – we can engineer a cleaner, more resilient New Zealand.

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Engineering New Zealand would like to acknowledge everyone who helped bring this publication to life, including:

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