Energy transition roadmap

Supporting an efficient transition to a low-emissions energy system

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Electricity Authority
Te Mana Hiko

Contents

1 The transition to a low-emissions energy system

1.1 New Zealand has committed to achieving net zero emissions by 2050, and the Government has set an aspirational goal to achieve 100% renewable electricity by 2030.

1.2 As signalled in the Government's recently-released consultation on the first emissions reduction plan (ERP), a well-managed transition to a low-emissions energy system will be critical to New Zealand meeting that goal[1]:

> *As the sectors transition over the next 30 years, we must ensure that:*
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> - *energy remains accessible and affordable to support the wellbeing of all New Zealanders*
> - *energy supply is secure, resilient and reliable throughout the transition and beyond*
> - *energy systems support economic development and productivity growth aligned with the transition.*

1.3 Earlier this year, the Climate Change Commission referred to the need for the regulatory regime for electricity to continue to adapt, to ensure the sector can deliver "*abundant, affordable, and reliable low-emissions electricity*."[2]

1.4 It is clear that the electricity sector has a critical role to play in the transition to a low-emissions energy system. With a focus on reducing emissions, reducing reliance on fossil-fired generation, and the need for billions of dollars of new investment to do so, the transition needs to be achieved without the other two limbs of the energy 'trilemma' – security or affordability, both of which are critical to consumers – being compromised.

1.5 We recognize and embrace electricity's role in supporting New Zealand's climate ambitions, and set out in this document the key activities we are undertaking to support that transition occurring as swiftly and efficiently as possible.

[1] ERP consultation document, page 81. Available online at https://environment.govt.nz/publications/emissions-reduction-plan-discussion-document/

[2] Climate Change Commission's final advice, section 15.1.3. Available online at https://www.climatecommission.govt.nz/our-work/advice-to-government-topic/inaia-tonu-nei-a-low-emissions-future-for-aotearoa/

2 Scenarios for the future

2.1 In large part due to the global push to reduce emissions, there are a number of significant, generational shifts occurring in electricity sectors internationally.

2.2 We referenced these shifts in our 2020 discussion paper on our strategy reset[3]. They include:

- The strengthening of the key trends referred to commonly as the 'three Ds':
  - decentralisation – the increase in deployment and use of distributed energy resources (DERs), particularly by consumers, and the resulting shifts towards multi-directional power flows on networks, and increases in the number of consumers actively participating in energy markets (which is linked to an emerging fourth 'D', the 'democratisation' of energy)
  - digitisation – the use of smart, digital technology to harness, control and automate these DERs in particular, new ways for consumers to engage using technology, and increases in artificial intelligence
  - decarbonisation – the global drive to reduce carbon emissions, which includes both reducing emissions from electricity generation, and reducing emissions from broader energy uses by switching to lower-emissions sources of energy such as electricity.
- The evolution and significantly reducing costs of technology, especially in relation to electricity generation, consumption and storage, at both large and small scales.
- Increasing disruption to traditional electricity value chains and business models, with the number and types of links in the chain, the number of participants involved, and the range of models employed by these participants all increasing.

There are clear trends in sector evolution

2.3 The shifts above are manifesting in different ways, and in recent years many different scenarios for the future evolution of the New Zealand power system have been developed[4].

2.4 While no one can predict the future accurately, there are a range of directional trends that are common across most of these scenarios:

1. Control and operation of the supply-side of the power system will shift from being characterized primarily by a small number of large power stations, to a more decentralized, hybrid comprising some large power stations and a very large number of small power generating facilities
2. The costs of developing wind and solar generation, and other new technologies such as batteries, will continue the decline of recent years
3. The proportion of supply met by variable renewable sources, such as wind and solar, will increase (with the wind and solar generation being non-synchronous)
4. Generation from existing fossil-fuel fired stations, such as gas and coal, will decline (meaning a reduction in the quantity of synchronous generation capacity)
5. Demand for electricity from heat and transport applications will increase as those parts of the energy sector seek to reduce their emissions profiles; however,

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[3] See https://www.ea.govt.nz/about-us/strategic-planning-and-reporting/strategy-reset-2020/strategy-reset-2020/

[4] We recently published a review of a number of these scenarios, undertaken by the Sapere Research Group. This is available online at https://www.ea.govt.nz/development/work-programme/risk-management/future-security-and-resilience-project/consultations/.

developments in energy efficiency, in New Zealand and internationally, will continue to place downward pressure on demand growth

6. Advances in technology mean the demand-side of the power system will become significantly more flexible and active in the market, with demand-side technology able to provide services to the power system that had previously been the realm of the supply side only

2.5 Each of the key shifts in 2.2 above, and the directional trends predicted in scenarios, apply to the power systems of most developed economies. This gives rise to common challenges and opportunities, and there are benefits to decision-makers sharing and collaborating internationally[5].

2.6 However, New Zealand's power system is also unusual in many respects, including:

(a) It is not electrically connected to any other countries

(b) The proportion of renewable electricity generation already exceeds 80% annually, and, since the electricity market started in 1996, there have been no explicit subsidies supporting investment in new renewable generation

(c) With a high proportion of hydro generation, backed by a material quantity of hydro storage, New Zealand's renewable generation has much more flexibility than other countries are likely to benefit from, but it is also more exposed to extreme inflow sequences

(d) Relative to the size of the system, both the demand and supply sides contain some large, "lumpy" components (for example the Tiwai Point aluminium smelter and Huntly Rankine units), the future of which is highly uncertain.

2.7 Ongoing work by the Authority's Market Development Advisory Group (MDAG) has highlighted that New Zealand will be at the 'bleeding edge' of transitioning to a 100% renewable electricity system within the context of a deregulated electricity market[6].

Combinations of trending factors can lead to very different outcomes

2.8 While each of the trends listed above is clear individually, how they will combine in future is not. In scenario modelling, the level to which each trend is dialled up or down, in concert with the others, makes a significant difference to projections for:

- the level and shape of electricity demand
- types and locations of generation developed
- quantities of fossil fuel burned, and associated emissions
- power system security and resilience
- electricity price levels
- electricity price volatility

[5] The Authority has endorsed the *Regulatory Energy Transition Accelerator* initiative, launched recently at COP26, which will support global energy regulators working together on transition-related issues. See https://www.retatheaccelerator.org/ for more information.

[6] See https://www.ea.govt.nz/development/advisory-technical-groups/mdag/mdag-price-discovery-project/ for more information.

2.9 For example:

(a) future demand for electricity will be influenced by (among other factors) population growth, electrification and economic growth, but will be moderated by the impacts of increased energy efficiency

(b) the costs of incremental new generation investment in the future will be influenced by the rate at which development costs have declined (largely influenced by rate of development overseas), but also by how many of New Zealand's better-performing generation sites have already been developed.

2.10 Understanding the range of potential scenarios is critical for decision-making. This range may never have been as broad as it is today.

2.11 In response to this uncertainty, participants in the industry develop portfolios of options that can be executed if and when the right conditions emerge. These options are not costless and take time to develop. Some of these options are being executed now, some will be in future, and some many never make it past the conceptual stage.

2.12 Awareness of the wide range of future scenarios, the risks of path dependence and the benefits of optionality, is also critical for policy makers and regulators alike. Our rules need to recognise the level of change in the sector and the uncertainty faced, and to support participants in making the best decisions they can, for the long-term benefit of New Zealand's electricity consumers.

3 Key shifts, opportunities and challenges

3.1 As the sector evolves over the coming decades, participants and rule-makers will be presented with a range of challenges and opportunities. These include:

(a) Realising the full benefits of distributed energy resources

(b) Supporting increased demand for new electricity infrastructure and the need to develop this at pace, without over-spending

(c) Managing the impact of evolving weather-driven variability on generation levels and network resilience

(d) Managing declining demand for fossil-fuel fired generation (while it is still required to support system reliability)

(e) Allocating and managing financial risks

3.2 Each of these challenges and opportunities are covered in the remainder of this section, with some of the key questions the Authority is considering highlighted .

Realising the full benefits of distributed energy resources

3.3 Technologies such as solar panels, batteries and electric vehicles mean consumers can produce and store their own electricity. Smart controls for equipment and appliances, such as 'smart' hot water cylinders, allow consumers and those acting for them to more easily control when and how they use electricity.

3.4 Technologies used to generate, store, or manage energy that are not connected directly to the transmission network are referred to as DER. As well as buying electricity, consumers with DER can participate in the market as sellers of electricity and related services.

3.5 New technology is also providing some consumers with more choice. New and existing suppliers are competing to win customers by offering innovative products and services that reflect consumer preferences. A new cohort of "flexibility traders" are emerging to manage services for consumers and monetise the latent flexibility in their premises. The result will be a change to the decades-old electricity supply model dominated by large-scale and specialised electricity businesses.

3.6 However not all consumers will have this opportunity, and the benefits of DER can be harnessed to reduce electricity costs to all.

3.7 As the country transitions, electrification of transport and process heat will create a substantial increase in electricity demand going through distribution networks. Many consumers will use more DER, and there will be more connections to the grid.

3.8 Empowered consumers will take control of their energy and participate in the electricity system in new ways. It is critical that products and services provided to consumers by the competitive parts of the sector evolve to meet changing consumer needs. System settings must enable innovation to occur, ensuring the market is disciplined by strong competitive pressure to continue to deliver what customers want and need at an affordable price.

Key questions and choices

(a) What barriers exist to the deployment of DER, and how should these be addressed?

(b) What do the sector and its regulators have to do to enable DER to monetise the full 'value stack' of benefits that may otherwise be unrealised?

(c) How do we ensure the benefits accrue to all consumers, not just for those who own them?

(d) How should technology standards provide a foundation for realising these benefits, and managing the challenges arising from increased penetration of DER?

(e) What roles should different parts of the sector play in relation to ownership, procurement and operation of DER?

Supporting increased demand for new electricity infrastructure and the need to develop this at pace, without over-spending

The generation investment challenge is significant, but achievable

3.9 There are long lead times in energy infrastructure investment, power stations are capital-intensive and long-lived, and parties are making decisions right now that will impact the sector for decades to come.

3.10 Managing the power system is complex. It requires electricity supply and demand to be balanced over multiple time periods:

(a) Hour by hour, demand must be met by supply from power stations in order to keep the lights on

(b) Month by month, station operators must plan their generation output to match demand, particularly if they have a finite and uncertain amount of fuel – as is the case with hydro generation stations

(c) Year by year, New Zealand must keep building new power stations to make sure the increasing demand can continue to be met, especially as existing power stations are retired.

3.11 This is the primary role of the wholesale market. It sends participants signals of the state of the demand-supply balance now and into the future, so that they can make decisions appropriately.

3.12 The reliability provided by generation and transportation infrastructure, is not costless, however. Trade-offs must be made. In order to keep the system in balance in the long term, New Zealand needs the right infrastructure built at the right times, in the right places:

(a) Build too little, and some demand may be unserved (through brown-outs or black-outs), while other demand may have to be met through expensive forms of generation

(b) Build too much, or in the wrong places at the wrong times, and more capital investment costs may need to be recovered than consumers can afford.

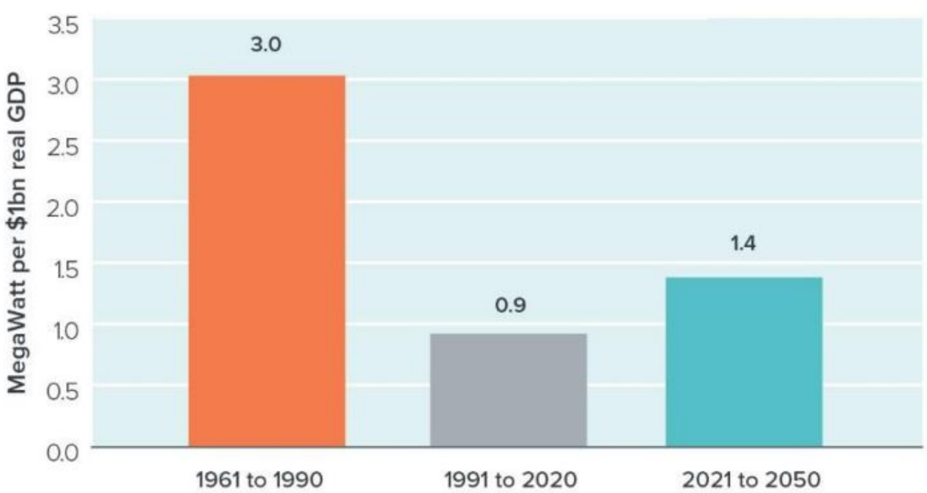
3.13 While the current wholesale market model is not perfect, it has been very successful. As we highlighted in our submission to the Climate Change Commission[7], around 1600 MW of new renewable generation has been built in New Zealand by investors since the market started, 25 years ago, alongside around 2000 MW of new thermal generation. Around 1500 MW of thermal generation has been retired.

3.14 Most of this new development (around 3000 MW) occurred in the first 15 years of the market, prior to the decline in load forecasts. However, in the past year alone, several hundred MW of new investment has been announced and committed. Electricity participants have shown they are up for the challenge.

3.15 Future investment will come from a much wider range of parties than previously, including households committing their own capital to rooftop solar generation. The role of Government investment, alongside private investment, is being explored as part of the New Zealand Battery Project[8].

3.16 While the rate of investment will need to increase over what the market has achieved to date, recent analysis by the Infrastructure Commission shows that, in relative terms, the required pace of investment relative to GDP is actually not as great as New Zealand achieved in the latter half of the 20th century – albeit that was achieved within a significantly different context[9]:

Average generation capacity built each year. relative to GDP



Source: Te Waihanga and Electricity Authority

3.17 The investment challenge is not limited to electricity generation capacity. Electrification of transport and process heat will create a substantial increase in electricity demand going through both the transmission system and distribution networks, increasing the required sizes of those networks and creating new challenges for managing the congestion on those networks.

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[7] Available online at https://www.ea.govt.nz/about-us/what-we-do/working-with-other-agencies/

[8] See https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/low-emissions-economy/nz-battery/

[9] See Infracom's strategy document, section 6.1.3. Available online at: https://www.tewaihanga.govt.nz/strategy/new-zealand-infrastructure-strategy/

3.18 It will be critical that these networks are operated and maintained as efficiently as possible, that all alternatives to traditional investment are considered, and that further investment in those networks is minimised.

Key questions

(a) Will the existing wholesale market design provide sufficient incentive for the required rate and quantity new generation required to meet New Zealand's targets? If not, what changes to the design may be required to provide a more certain and conducive investment environment?

(b) What are the barriers to independent renewable generation of all scales being developed, connected and operated, and how can these be addressed?

(c) How do we ensure we build the most efficient combination of electricity generation and electricity transportation infrastructure to meet demand?

(d) How do we increase the pace of reform to distribution pricing to ensure price signals support efficient use of and investment in these networks?

Managing the impact of evolving weather-driven variability on generation levels and network resilience

3.19 New Zealand is a long, thin archipelago in the middle of a vast ocean, subject to highly variable weather patterns. With hydro power accounting for well over half of New Zealand's electricity generation, managing this variability has been something the power system has been designed to cope with for decades.

3.20 Generation that is able to increase output on demand to support a decline in renewable output is referred to as "firming" generation. Thermal generation, fuelled by coal and gas, has been New Zealand's key source of firming generation for many decades.

3.21 As the use of these fuels declines, the system will need new ways of managing this risk. Geothermal generation has a much more stable output profile, and solar and wind generation are less variable on a month-to-month basis than hydro. More generation from these sources will allow precious hydro storage to be used in a different mode.

3.22 However, increased reliance on the wind and sun for electricity creates different risks to manage. Both forms of generation are described as 'intermittent', 'variable' and/or 'non-dispatchable', in that they produce electricity when the sun is shining or wind is blowing, but not otherwise, and their output cannot be increased on demand.

3.23 The system will need to be able to manage periods when the wind is not blowing and the sun is not shining. In Germany, the phenomenon referred to as '*dunkelflaute'* describes periods of very low levels of wind and solar generation across the entire country (and, occasionally, the whole continent). However, weather patterns in continental Europe are materially different to those in New Zealand, presenting a very different risk profile. In New Zealand there are fewer periods of low wind and solar output, and a much lower chance of prolonged shortages for multiple days, but periods of low output will still occur and have to be managed.

3.24 As the proportion of variable renewables increases, so will the periods in which output from renewable generators *exceeds* demand for electricity across the grid. This is a different risk to manage compared with that above, but some of the solutions, including increased flexibility on the demand side to absorb excess generation, could be the same.

3.25 In general, the *flexible* components of the power system, including dispatchable generation, flexible demand and storage, will increasingly play the role of balancing the fluctuating output of the *inflexible* components of the system, including wind and solar generation – presenting different challenges to power system operation over hours, weeks and months.

3.26 A changing climate may also increase the occurrence and severity of extreme short-term weather events, placing increased pressure on the resilience of transmission and distribution networks.

Key questions

3.27 Do the changes to variability warrant enhancements to the current wholesale market design, particularly in relation to short-term scheduling?

3.28 How do we enable new forms of flexible technology, especially on the demand side, to provide responsiveness and assist with balancing variable renewable output?

3.29 How do we ensure the power system remains secure and resilient in the face of not just a significantly changing generation mix but also increasing variability in weather?

Managing declining demand for fossil-fired thermal generation (while it is still required to support system reliability)

3.30 Flexibility in the New Zealand power system has traditionally been provided by hydro plant, and, as mentioned above, fossil-fired thermal plant – especially when generation from hydro plant has been restricted due to low inflows.

3.31 As more renewable generation is developed, the role of fossil-fired thermal generation will evolve. Fossil-fired thermal generation will be used less and less as "baseload" (i.e. running 24/7), instead generating only when renewable sources are not available. The average running levels of thermal generation will decrease[10], and become proportionally more variable week-to-week and year-to-year[11]. In a 100% renewable electricity system, there would be no fossil-fired generation at all.

3.32 While thermal generation is still operational, the owners of this plant will earn money through both operating in the spot market, and selling insurance-type contracts to other parties – as they do today. As the transition progresses, the expected earnings for each thermal plant (from all sources of revenue) will eventually be exceeded by the expected costs of keeping it open, signalling that the generation is no longer required by the market.

3.33 This will occur naturally as the system evolves and alternatives to the thermal plant are commissioned. As mentioned above, since 1996 the market has already retired around 1500 MW of thermal plant that the owners deemed was no longer economic to retain.

3.34 Provided that market participants (collectively) are willing to contract with such "socially beneficial" generation when it is still required, thermal plant will not retire prematurely and reliability will not be compromised. The retirement will be "orderly". However, issues

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[10] See the Gas Industry Company's final report on its gas market settings investigation for further information, available online at: https://www.gasindustry.co.nz/work-programmes/gas-market-settings-investigation/developing-2/final/

[11] See Figure 4.2 on page 49 of the Interim Climate Change Committee's final report, available online at https://www.iccc.mfe.govt.nz/what-we-do/energy/electricity-inquiry-final-report/accelerated-electrification-evidence-analysis-and-recommendations/

will arise if risk appetites do not align, there are any barriers to contracts being struck, and/or the collective commercial incentives do not align with national interests.

3.35 Further, much of the existing thermal capacity is nearing (or is well past) the end its design life, increasing concerns around its reliability.

3.36 The changing role of fossil-fired thermal generation, and potential change to earnings profiles, creates a challenge to its owners. It also creates a more uncertain demand for fuel from upstream supplies, which, as signalled by the Gas Industry Company, will require a more flexible fuel supply.

3.37 As more providers of thermal “firming” capacity exit the market, but what remains is still required, it also raises questions about the competitiveness of the sub-market for such capacity.

Key questions

3.38 Are there any barriers to the thermal generation that is required by the system achieving sufficient revenue, either through the spot or hedging markets, to enable it to stay open?

3.39 Is any intervention required to support retention of thermal generation that might otherwise retire but is still required to support reliability?

3.40 Does there need to be any intervention in the market to promote more “orderly” exit of fossil-fired thermal plant?

3.41 What is the potential for biofuel-fired thermal generation in future?

Allocating and managing financial risks

3.42 Volatile spot prices have always been a feature of New Zealand’s electricity market, however the patterns of volatility are materially different to other countries. Other markets typically experience much greater levels of short-term (within-day) volatility, but in New Zealand prices can rise for weeks or months on end due to hydro shortages.

3.43 Price volatility in and of itself is not a problem, provided it is providing accurate, efficient and actionable signals and can be managed. In fact, it creates opportunities for new businesses and new technology, such as batteries or flexible EV charging. The Authority ensures mechanisms are available for users to manage the risks of this volatility.

3.44 In future, it is likely that the nature of price volatility will change, particularly as the composition of the supply and demand sides evolves. Short-term volatility will likely increase due to the increasing prevalence of wind and solar generation, but be mitigated by increasing flexibility on the demand side.

3.45 Some significant step changes to the power system also create uncertainty for participants. These include the retirement of large thermal plant, and large industrial consumers such as the Tiwai Point aluminium smelter. Changing fuel and carbon prices will also play a role, including after fossil-fired thermal plant exits the system.

3.46 It will be important that there is as much visibility of future prices for electricity as there is in current prices, and that liquidity in products of all time durations enables all participants to trade with confidence.

Key questions

3.47 Are new standard products or agreements required to support the development of and purchase of power from new generation, specifically?

3.48 Are any changes to the market required to enable new-entrant generators and retailers to compete on a level playing field with established participants?

3.49 Will market participants on both the demand and supply sides have the tools and capability they require to manage financial risks in a world of increased volatility?

3.50 Does the impact of so-called “lumpy” retirements from both the demand and supply sides require special attention?

3.51 How do we ensure sufficient competition on both the demand and supply sides of financial risk management products?

3.52 Do more risk management products need to be introduced into the market – from cap products to standardised power purchase agreements?

4 Our response – facilitating an efficient transition

4.1 The Authority's purpose is "*to enhance New Zealanders' lives, prosperity and environment through electricity*"[12]. Facilitating an efficient transition to a low-emissions energy system is one of the Authority's five strategic ambitions.

4.2 The Authority recognises the opportunities and challenges highlighted in the previous section. We have developed a programme of work designed to address the questions set out above, and many more critical issues. These activities are represented in the roadmap appended to this paper.

4.3 The roadmap is disaggregated into six key categories of work, or 'swim lanes', which describe the critical and interrelated focus areas through the transition:

(a) **Generation investment and reliability**: Demand and supply are balanced across all time periods, from hour-to-hour to year-to-year. Resources are allocated efficiently across time periods, and new generation to meet demand built at the right times and in the right places, minimising costs to consumers.

(b) **System security and resilience**: The power system is robust to adverse events, can adapt to changing risks, and is able to recover from external shocks.

(c) **Distributed energy resource integration and investment**: The power system embraces DER and consumers are able to participate fully. The full value and benefits of these resources are realised not just for those New Zealanders owning and operating the DER, but also for those who do not and cannot own DER.

(d) **Efficient network infrastructure investment and operation**: Existing network infrastructure is used as efficiently as possible and new investment is only made when absolutely required, minimising costs to consumers. The combination of new electricity generation and transportation infrastructure is optimised, so that new transmission and distribution infrastructure is built at the right times and in the right places.

(e) **Monitoring, compliance and enforcement**: The electricity system is being closely monitored and managed. It is clear that participants are held to account for high standards, behaviour that negatively impacts consumers is eliminated, and the transition is being facilitated efficiently. Trust and confidence for the market-based regime, and in the Authority as the regulator, is high.

(f) **Risk management through the transition**: In an increasingly volatile and uncertain world, parties have the mechanisms and capability to be able to trade with confidence, manage financial risks and meet their businesses' needs.

4.4 The first four of these categories align with the "four key areas of need" identified by the Australian Energy Security Board (ESB) as part of its widescale, multi-year review and programme for Australia's future market design[13]. We have also compared the recommendations from the ESB's work with our own activity.

[12] See https://www.ea.govt.nz/about-us/strategic-planning-and-reporting/strategy-reset-2020/ for more information.

[13] Available online at https://esb-post2025-market-design.aemc.gov.au/options-paper

Transformational workstreams

4.5 The roadmap distinguishes a number of the workstreams as being 'transformational'. These are workstreams that have the potential to have a significant, once-in-a-generation impact on aspects of the core market design. These workstreams are explained in the following paragraphs.

4.6 As mentioned later in this section, we are also undertaking several significant reviews of the electricity market currently (such as the Wholesale market competition review), each of which has the potential to give rise to a number of important and transformational policy workstreams.

Future security and resilience[14]

4.7 The multi-year *Future security and resilience* workstream is investigating challenges and opportunities to maintaining a secure, stable and resilient power system in the face of technological and other changes.

4.8 This project forms part of the Authority's response to the Government's Electricity Price Review[15] – in particular, recommendation G2, to examine the security and resilience of electricity supply.

4.9 The initial focus of the *Future security and resilience* workstream is on maintaining security, stability and resilience of the national power system in and close to real time. In other words, it is not assessing the power system's ability to maintain a balance of demand and supply over periods of longer than a few days (often referred to as "adequacy").

4.10 There are key interrelationships between *Future security and resilience* and the following workstreams:

(a) Examining wholesale market operation under 100% renewables (undertaken by the Authority's Market Development Advisory Group, MDAG)

(b) Updating the regulatory settings for electricity distribution networks.

4.11 The first of these is the primary workstream addressing spot market operation and adequacy as New Zealand transitions towards 100% renewables.

4.12 The latter is the Authority's primary workstream addressing the future security and resilience of distribution networks in the coming decades. The Authority recently consulted on a discussion paper launching this workstream[16], and received many submissions. Analysis of the feedback received will inform the direction of that work, and of any work relating to distribution networks to be undertaken under the *Future security and resilience* workstream.

4.13 Work undertaken under the *Future security and resilience* workstream will form the basis of the *Joint development programme*[17] between the Authority and Transpower as the system operator for the coming years.

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[14] See https://www.ea.govt.nz/development/work-programme/risk-management/future-security-and-resilience-project/

[15] See https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-consultations-and-reviews/electricity-price/ for more information.

[16] Available online at https://www.ea.govt.nz/development/work-programme/evolving-tech-business/updating-regulatory-settings-for-distribution-networks/

[17] See https://www.ea.govt.nz/operations/market-operation-service-providers/system-operator/joint-development-programme/ for more details.

Examining wholesale market operation under 100% renewables[18]

4.14 Electricity markets worldwide, including New Zealand's, have been designed on the assumption that a material proportion of generation is fuelled by fossil fuels. Fossil-fuelled thermal generation is characterised by relatively low investment costs, and high operating costs.

4.15 In contrast, renewable technologies, such as solar and wind generation, have relatively high investment costs but very low short-run costs of generation.

4.16 One of the Authority's two standing advisory groups, MDAG, is undertaking a project investigating how the wholesale electricity market might operate (including price discovery and new investment in generation) under a 100% renewable electricity supply.

4.17 Within this context, MDAG's project is looking at several important questions, including the following:

(a) How the electricity spot market will promote efficient operation when a high proportion of generation capacity has low or zero short-run marginal costs of operation

(b) How stored water will be priced and allocated across time periods, without fossil-fuelled thermal plant in the market

(c) How the wholesale market will enable efficient investment when supply is dominated by generation with low short-run marginal costs

(d) How to ensure efficient pricing in extended periods of supply scarcity, such as dry years.

4.18 MDAG is currently developing a problem definition paper and intends to publish this for feedback in early 2022.

Updating the regulatory settings for electricity distribution networks[19]

4.19 This work programme aims to ensure the regulatory settings in the electricity distribution sector support the transition to a low-emissions energy system while promoting competition, reliability and efficiency for consumers' long-term benefit.

4.20 The work programme has a particular focus on increasing competition and consumer participation in flexibility markets on distribution networks, i.e. the markets for buying and selling services from controllable DER. The work builds on several years of investigation in this area by the Authority's Innovation and Participation Advisory Group (IPAG).

4.21 Globally, and in New Zealand, the quantity of DER connected to the power system is set to increase significantly in coming decades. As mentioned earlier, it is important that the full value and benefits of these resources are realised not just for those that own and operate the DER, but also for those consumers who do not and cannot own DER.

4.22 The desired outcome is for sector participants to have the ability, information and incentives to make efficient investments in both network and non-network solutions – for instance investing in DER capable of providing network-supporting services, rather than upgrading distribution networks. Where non-network solutions are more efficient, the desired outcome is for these services to be procured through a competitive framework.

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[18] See https://www.ea.govt.nz/development/advisory-technical-groups/mdag/mdag-price-discovery-project/

[19] See https://www.ea.govt.nz/development/work-programme/evolving-tech-business/updating-regulatory-settings-for-distribution-networks/

4.23 More efficient investments can lower prices for consumers – not just for those consumers who own DER, but for those who do not. More investment in DER, including in renewable generation, batteries and demand response, will support the shift to lower emissions by decreasing peak demand (or, at least, constraining growth in peak demand). Competition in this area can lead to consumers having more choice of both supplier and type of service, and will help drive costs down.

4.24 A cost benefit analysis commissioned by the Authority and undertaken by Sapere Research Group[20] estimated that, if the full benefits of DER were to be realised, the net benefit from 2021 to 2050 is expected to be $7 billion in net present value. Of this, $2.8 billion accrues to consumers while $4 billion will go to the DER owners and operators.

4.25 The Authority is currently analysing feedback on a discussion paper and developing its next steps in this work programme.

Implementing real-time pricing in the electricity wholesale market[21]

4.26 As well as providing much-needed flexibility to distributors, DER, including demand-side flexibility (such as EV chargers and hot-water heating), battery storage systems and distributed generation – also have significant potential to balance fluctuations in nationwide supply from large-scale, variable generation like wind and solar.

4.27 Harnessing DER will be an efficient method for managing this generation variability, but it will require coordination in real-time. If this responsiveness is uncoordinated, demand and supply will not be balanced as effectively as possible.

4.28 Making the most of the potential flexibility available will rely on electricity market participants, and the owners and operators of DER, seeing clear price signals in real time they can respond to with confidence. In fact, in future, there will be so many resources connected to the electricity system that the *only* way to manage them may be through price signals[22].

4.29 The real-time pricing (RTP) project will promote the efficient integration of increased levels of DER and variable generation (e.g. wind and solar) into the power system in two ways:

(a) **Settlement pricing based on real-time dispatch pricing**: this will mean that owners and operators of flexible resources can act on published pricing in real time, knowing that the price will be directly related to the final settlement price.

(b) **Introduction of Dispatch Notification participation:** Dispatch Notification is a new, low-cost method for DER (including demand response) to signal their price responsiveness in the market. This will allow response to pricing by DER to be co-ordinated with other market resources. This will lead to more efficient and stable pricing outcomes, and greater participation by DER in the wholesale price-discovery process.

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[20] Available online at https://www.ea.govt.nz/development/work-programme/evolving-tech-business/updating-regulatory-settings-for-distribution-networks/

[21] See https://www.ea.govt.nz/development/work-programme/pricing-cost-allocation/spot-market-settlement-on-real-time-pricing/

[22] See Hogan, William W. "Market Design Practices: Which Ones Are Best? [In My View]." IEEE Power and Energy 17.1 (January/February 2019). In this paper, Professor Hogan states that "*The central control of distributed resources would not be feasible, and prices must provide the needed incentives. Failure to provide the right price signals will lead to distributed decisions that would undermine efficient operations.*".

4.30 The design and policy decisions for RTP have already been made. RTP is set to begin operation in New Zealand in late 2022, with the Dispatch Notification product launched early in 2023.

A new Transmission Pricing Methodology[23]

4.31 This workstream is developing a new approach to paying for investments in the national electricity transmission grid: a benefit-based approach. Under this approach, those who benefit from transmission investments will pay for them.

4.32 If the current proposal is implemented, benefit-based charges will replace the main charges under the existing transmission pricing methodology (TPM) – the regional coincident peak demand (RCPD) and the high voltage direct current (HVDC) charges.

4.33 The Authority considers that the new approach to paying for transmission assets will deliver significant benefits to consumers and give electricity consumers and generators much-improved signals of the costs and benefits of using the transmission grid. Overly-high transmission charges for using electricity at times when consumers most want it will be removed, and the new approach will stop rewarding parties that shift costs on to other consumers for no overall benefit.

4.34 The proposed new TPM will also promote the right investment at the right time in renewable generation, transmission and electrification of industrial processes and transport.

4.35 Efficient investment and use decisions by generators, distributors and consumers will result in electricity prices over the long term being lower than they would otherwise be. Lower electricity prices will support the electrification of transport and process heat, whilst supporting a transition to meet New Zealand's low-emissions challenge at least cost to consumers. The proposed new TPM will ensure a level playing field for batteries (and other storage) so that they are not at a competitive disadvantage compared to other generation. The proposed new TPM will help to address the first-mover disadvantage issue for new transmission connection investments (a potential barrier to renewables/electrification).

4.36 The Authority is currently consulting on the proposed new TPM. If the new TPM is implemented, focus will then shift to ensuring the projected benefits of the proposal are realised.

Faster reform to efficient electricity distribution pricing[24]

4.37 This programme of work both supports the electricity sector and drives faster reform to efficient electricity distribution pricing.

4.38 Distribution pricing matters; the distribution component makes up approximately 27% of the average electricity bill.

4.39 The benefits of pricing reform are substantial across all consumers – residential, commercial and industrial – as efficient distribution pricing plays a critical role in reducing network upgrade and expansion costs, and ensuring distributors also consider network alternatives. It also results in more choice and flexibility for consumers and enables

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[23] See https://www.ea.govt.nz/development/work-programme/pricing-cost-allocation/transmission-pricing-review/

[24] See https://www.ea.govt.nz/development/work-programme/pricing-cost-allocation/distribution-pricing-review/

consumers to make better technology investment decisions. This will result in lower prices over the long term.

4.40 As the proposed new TPM is likely to remove the peak pricing signal in transmission pricing, efficient distribution pricing becomes more urgent. Also, as electricity load increases, from process heat and uptake of EVs, some networks will face congestion, again meaning efficient pricing becomes more urgent.

4.41 The Authority recently consulted on refreshed guidance for distributors. This workstream also links closely to the Authority's *Updating the regulatory settings for the distribution sector* work programme.

Significant reviews of the electricity market and key events

4.42 As well as these transformational initiatives, the Authority is also undertaking several significant reviews of the electricity market currently, including:

(a) The wholesale market competition review[25]

(b) Phase 2 of the review into the events of 9 August 2021[26]

(c) Review of the events of early 2021, driven by low hydro inflows and the tight gas market.

4.43 Each of these reviews will be considering issues critical to the low-emissions transition, and each has the potential to give rise to a number of important and transformational policy workstreams.

4.44 Further, the final report from the Government's own investigation into the electricity supply interruptions of 9 August 2021 has recently been released[27]. Its conclusions mirror many of the challenges and opportunities already being considered in the Authority workstreams above, and are highly relevant to the transition in general.

[25] See https://www.ea.govt.nz/monitoring/enquiries-reviews-and-investigations/2021/wholesale-market-competition-review-2/

[26] See https://www.ea.govt.nz/monitoring/enquiries-reviews-and-investigations/2021/electricity-authority-review-of-9-august-2021-event-under-the-electricity-industry-act-2010/

[27] Available online at https://www.mbie.govt.nz/dmsdocument/17988-investigation-into-electricity-supply-interruptions-of-9-august-2021

5 Next steps for the implementation of the roadmap

5.1 Electricity sectors globally are experiencing a significant amount of change. As discussed above, while the overall trends in the evolution of the sector are clear, there is a great deal of uncertainty over how individual factors will combine and which scenario(s) will emerge.

5.2 In some respects, New Zealand will be at the ‘bleeding edge’ of the transition, but in others it can learn from overseas experience.

5.3 There is a significant level of work underway to supporting the transition to a low-emissions economy, both by sector stakeholders and across a number of policy and regulatory streams. This includes the forthcoming development of a national energy strategy for New Zealand.

5.4 The Authority’s roadmap will therefore remain a living document, illustrating our priority workstreams at a point in time. It will help to provide transparency on the key initiatives we are undertaking, confidence that the multiple workstreams are consistent and fit together coherently, and that the inevitable boundary issues are being managed.

5.5 The document will be updated at regular intervals. As with any of the Authority’s workstreams, stakeholders are welcome to provide constructive feedback on it to ensure it remains fit for purpose.