New Zealand Electricity Distributor

Network Transformation Roadmap

April 2019

ena
electricity networks association

Abbreviations and Acronyms used

Acronym	Description
AMI	Advanced metering infrastructure
AMP	Asset management plan of an electricity distribution business
DER	Distributed energy resource (such as solar PV, distributed generation, electric vehicles, batteries, home energy management systems, and includes demand response)
DG	Distributed generation
DPWG	Distribution Pricing Working Group, an ENA working group
DR	Demand response
DSO	Distribution system operator
Dx	Distribution
EDB	Electricity distribution business
EEA	Electricity Engineers' Association
EIPC	Electricity Industry Participation Code
ENA	Electricity Networks Association (of New Zealand)
EV	Electric vehicle
GHG	Greenhouse gas
HEMS	Home energy management system
HILP	High impact low probability, usually used to refer to an event with low probability of occurrence, but which causes a high impact when it does occur

Acronym	Description
ICP	Installation control point
IMO	Independent market operator
IPAG	Innovation and Participation Advisory Group, an Electricity Authority advisory group
LED	Light emitting diode
LRMC	Long run marginal cost
LV	Low voltage (any voltage below 1,000 Volts, and in New Zealand electricity distribution refers to 400 Volt three phase / 230 Volt single phase electricity distribution network)
MV	Medium voltage (in New Zealand this refers to electricity distribution above 1,000 Volts, and is typically 11 kV and 33kV, but may also include 22 kV and sub-transmission owned by EDBs of 66 kV)
NTR	Network Transformation Roadmap
PV	Photovoltaic solar, in particular rooftop systems
SG	Steering Group for the NTR project
STWG	Smart Technology Working Group, an ENA working group
RAPS	Remote area power supply
RWG	Regulatory Working Group, an ENA working group
TOU	Time of use

Contents

Executive Summary

This Network Transformation Roadmap (NTR) has been developed for New Zealand electricity distribution businesses (EDBs) by the Electricity Networks Association (ENA). Its purpose is to provide information, insights, and recommended 'least regrets' actions for EDBs to navigate the changes in the way electricity distribution networks will be used in the future.

Recognising the uncertainties facing EDBs, the ENA's Smart Technology Working Group (STWG) formally began the development of the scenarios and roadmap in July 2017. It aims to best position EDBs to effectively and efficiently meet the future distribution service needs of consumers by guiding EDBs to plan and develop their networks and operations in a way that maintains flexibility in a period of disruptive change.

It also provides stakeholders with a coherent vision of the future role of electricity distribution networks in New Zealand.

The roadmap focuses on the intersection of new technologies with electricity distribution networks, rather than traditional aspects of electricity distribution. This is a challenge facing all electricity systems around the globe, and in developing this roadmap plans from other jurisdictions were reviewed and incorporated where appropriate.

Given the substantial uncertainty around development of new technologies and consumer behaviour, the roadmap compiles 'least regrets' actions that should be taken by EDBs – actions that, for the most part, are identified from common elements in the scenarios that underpin the roadmap and capture the uncertain future that EDBs face. The actions are for implementation over the next 10 years, in preparation for the changes to 2050.

For the purpose of developing the roadmap, the role of the EDB has been kept to its core function – providing a resilient electricity distribution service, such that electrical energy can be provided safely, reliably, efficiently and sustainably in the long-term interests of consumers.

The NTR provides a set of guidelines for EDB boards and senior management to consider when setting their strategies and future-focused plans. Its emphasis is on the new activities and functions EDBs will need to undertake in the next 10 years.

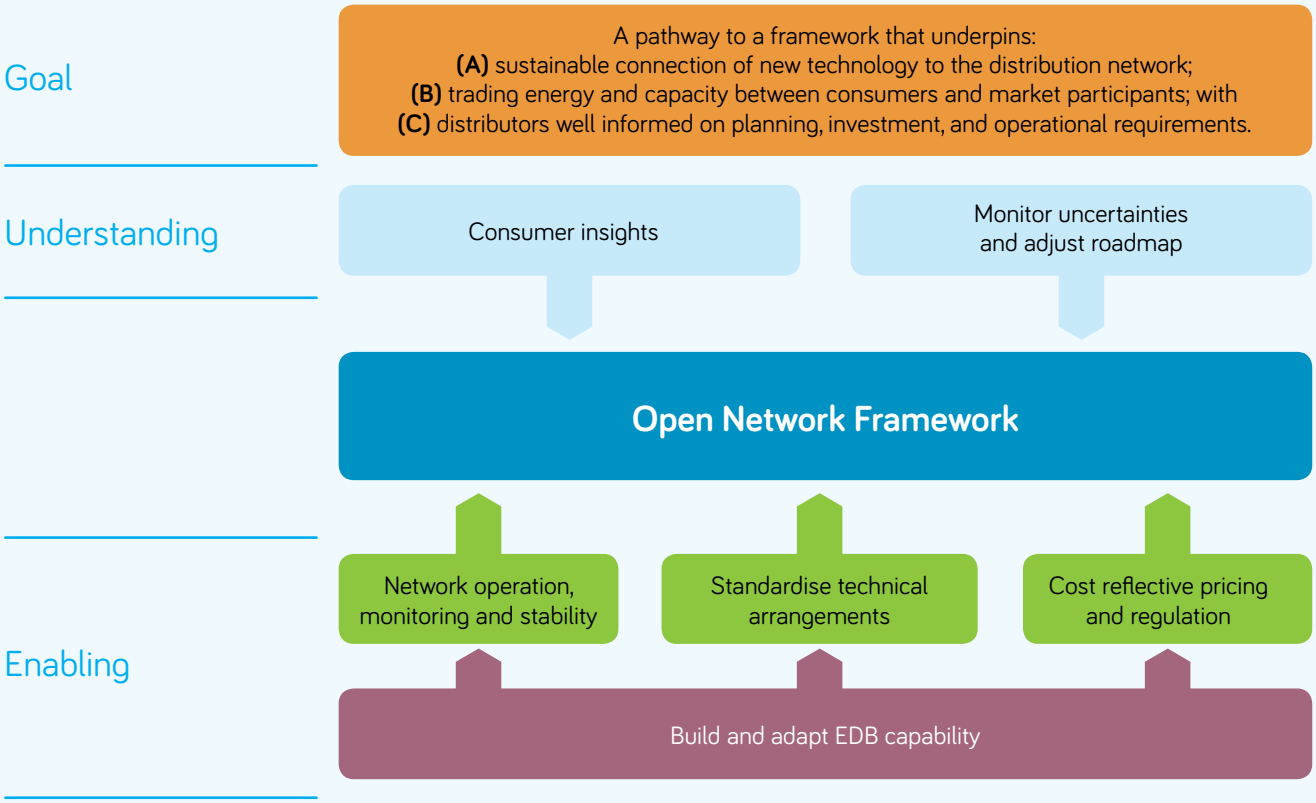
Roadmap focus and structure

The actions in the roadmap are grouped by programmes. An ***open network framework*** forms the centre of the roadmap and is one of its seven programmes. In the open network framework, consumers will be able to connect and operate any device, with appropriate consideration for:

- cost of access;
- network operation and system security for all users connected to the common network;
- standard equipment;
- and standard access arrangements.

The open network framework also enables the trading of electrical energy and capacity between consumers and market participants using the distribution network.

As shown in the roadmap representation below, six programmes within the NTR either provide understanding to inform the open network framework, or directly enable it.



NTR structure and relationship of programmes.

The Open Network Framework programme and the six constituent programmes informing and enabling the open network framework are detailed below.

Consumer Insights

Objective: Understand consumer motivations and behaviours to determine: (1) the impact on distributed energy resource (DER) deployment and consumption patterns; and (2) new load requirements.

- Access to smart meter data

  Progressively over time address barriers to half-hourly consumption data to understand emerging behaviours, and ultimately sub half-hourly and power quality data

- Understand DER deployment

  Data on DER deployment (location, type etc) available, moving to consumer understanding and scenario modelling to understand DER deployment possibilities

- New loads

  Start by understanding connection requirements (location and type) of new loads, move to actively planning for and delivering network services to new loads

- New distributed generation (DG)

  Understand new DG connection requirements. Develop and trial new DG connection standards, move to implementation consistently across all EDBs

Monitor Uncertainties and Adjust Roadmap

Objective: Stay abreast of technology developments and update the EDB industry. Update this roadmap to remain relevant.

- Monitor uncertainties

  Monitor uncertainties, megashifts and consumer behaviours regularly and feed into roadmap programmes where necessary

Open Network Framework

Objective: Access to the electricity distribution network by existing and new consumers and traders to connect and operate any equipment they desire (specifically DERs and new loads) with appropriate consideration of: (1) cost of access; (2) network operation and system security; (3) standard equipment; and (4) standard access arrangements.

- Enable distribution network trading

  Understand access requirements for DERs, open up access, and move to full and equal access to the distribution network as a vital platform for delivery of energy and capacity to and by consumers

- Third party DER and DR for network support

  Start by trialling DER and DR support to putting in place processes and systems for acquiring and using it, to DER and DR being an important contributor to network operation and support

- Demand response framework

  Work with regulators on the challenges of multiple users of DR – trial and move to full scale use of third party supplied DR to manage the distribution network

Cost Reflective Pricing and Regulation

Objective: Enable the open network framework through ensuring appropriate incentives are developed, including signaling appropriate long and short run prices to coordinate DERs for network and system support, and avoid congestion.

- Cost reflective pricing is an essential aspect of the open network framework
- Communicates the cost of using the distribution service for energy delivery to and from prosumers, and of the need for capacity for network support
- The NTR recognises the importance of cost-reflective, service-based pricing of distribution services in order to ensure efficient and effective use of the distribution networks now and in the future

(The ENA Distribution Pricing Working Group has been tasked with supporting EDB cross-industry efforts in pricing reform and is well advanced in its actions towards this outcome. The NTR reflects the mandate that group has to lead this work.)

Standardise Technical Arrangements

Objective: Provide a consistent method of connection of any equipment (DERs or appliances) across all EDB areas. Ensure equipment complies to approved standards to minimise its impact on the electrical power system.

- DER Connection Codes

  EDBs jointly develop and implement new agreed connection frameworks/codes, moving to regular and consistent use by all EDBs, with consistency maintained across all EDBs

- Appliance and DER equipment standards

  EDBs collectively assess and contribute to international standards to ensure they are appropriate for NZ, and adopt equipment standards appropriate to NZ. Test houses to approve equipment as compliant before being allowed on the network. All equipment connecting to the network is compliant to approved standards and codes, with consistency across all EDBs

- Cyber security and autonomous DERs

  Research appropriate cyber security standards and standards for autonomous DERs. Trial and implement standards to ensure stability of autonomous DERs

Network Operation, Monitoring, and Stability

Objective: Ensure the stability of the open network through deeper monitoring of the network and improved planning techniques.

- Low voltage (LV) network monitoring & visibility

  Roll out of LV monitoring systems with data management systems and provision of advanced metering infrastructure (AMI) data to assist with network management. Improve quality and type of monitored data over time. Lead to extensive knowledge of each LV network

- Network stability

  Research the implications of numerous autonomous DERs and methods of control. Trial control systems and implement control systems across EDBs (Note standardisation of these methods is covered in the previous programme)

- Provision of network information

  Investigate and trial provision of network information to operators, moving to regularly providing network information to operators, and extensive provision of information

Build and Adapt EDB Capability

Objective: Understand networks in greater depth, their ability to host DERs, congestion, and contracting for network support. Ensure working understanding of regulations and obligations of those.

- Network understanding

  Understand congestion in LV networks (which may include medium voltage networks). Understand the ability of the LV network to host DERs, and opportunities for DERs to mitigate congestion

- Contracting for network support

  Trial framing of EDBs' requirements for network support and introduce contestable procurement to discover a range of solutions. Develop the necessary processes to support contestable procurement of network support from trial experience. Move to regular practice, practiced consistently across all EDBs

- Asset management practice

  EDBs collectively explore, trial, and implement improved asset management practices and consistent frameworks across all EDBs

- Off grid power supplies

  Move from trialling remote area power supplies to best practice between EDBs and industry, practiced where it is more economic than traditional networks

1 Introduction

Traditional production and use of electricity are changing. Newly affordable technologies are disrupting generation, use, and consumer behaviour, driving unprecedented change and unpredictability in the electricity sector as well as creating opportunities.

These fundamental changes, and the consumer preferences and technology they give rise to, will have a profound impact on the electricity industry in the next 30 years.

These changes, or megashifts, include:

1. the requirement to meet climate change objectives, which can be achieved largely by switching energy use to renewable electricity;
2. new consumer technology, which is increasing the options for consumers to produce and store electricity, as well as use electricity in new ways; and
3. consumers choosing to adopt new technology and options that reflect their personal needs and desires, such as playing a role in meeting climate change objectives and engaging actively with their electricity supply.

Given the difficult-to-predict nature of future technology development and consumer behaviour, New Zealand electricity distribution businesses (EDBs) must plan in an environment of considerable uncertainty.

This Network Transformation Roadmap (NTR) has been developed for EDBs by the Electricity Networks Association's Smart Technology Working Group (STWG). Its purpose is to provide information, insights and recommended actions for EDBs to navigate the changes in the way electricity distribution networks will be used in the future.

It aims to best position EDBs to effectively and efficiently meet the future distribution service needs of consumers by guiding EDBs to plan and develop their networks and operations in a way that maintains flexibility in a period of disruptive change.

It also provides stakeholders with a coherent vision of the future role of electricity distribution networks in New Zealand.

Interacting drivers of change

The changes and megashifts are linked; the need of nations to reduce greenhouse gas emissions has given rise to clean energy technologies such as wind power, photovoltaic solar (PV), electric vehicles (EVs) and storage batteries, which in turn enable greater consumer choice and active engagement with electricity supply and/or electricity as a product.

With regard to reducing greenhouse gas emissions, and changes to traditional production of electricity, at one extreme is a potential increase in large-scale, centralised renewable generation. Accompanying this is the requisite capacity of the transmission and distribution infrastructure to transport greater volumes of electrical energy to the consumer. Renewable energy will provide a more efficient and emissions-free substitute for existing fossil fuelled processes such as industrial heating and transport.

At the other extreme is the growth of distributed generation (e.g. solar), storage and micro-grids. Such technology might be supplemented by energy-dense renewable fuels such as hydrogen or biofuels. Some energy end use might change to electricity (such as transport), while other uses continue with combustion, but with renewable fuels.

The reality is likely to be somewhere between these extremes, just as consumer behaviour will range between passive and active extremes, as identified in the scenarios that underpin this roadmap.

At the centre of the changes are consumers, who have increasing options for using electricity. They will exercise those options depending on the economics, ease of use, environmental attractiveness, and their circumstances, thereby exhibiting more individual behaviour than in the past.

However, no one knows exactly how consumer behaviour will evolve, nor what new technology will be available in the future and how consumers will use it.

Network adaptation

Also at the centre of these changes is electricity distribution, delivering renewable energy to almost every consumer, and increasingly providing them with the network services to sell their electricity.

It is the role of EDBs to support consumers in adopting new technology in the future, thereby facilitating innovation, and aiding the transition to renewable energy in order to meet climate change objectives.

Ultimately, consumers should be free to connect any new electrical technology they wish to the network, provided the cost of connecting that technology is communicated appropriately and the technology meets appropriate standards to ensure safety and reliability for all connected consumers.

1.1 Purpose and scope of the Network Transformation Roadmap

The roadmap focuses on the intersection of the new technologies discussed earlier with electricity distribution networks, rather than traditional aspects of electricity distribution.

Given the substantial future uncertainty, the roadmap compiles 'least regrets' actions that should be taken by EDBs – actions that, for the most part, are identified from common elements in the scenarios that underpin the roadmap and capture the uncertain future that EDBs face.

It provides a set of guidelines for EDB boards and senior management to consider when setting their strategies and future-focused plans. Its emphasis is on the new activities and functions EDBs will need to undertake in the future.

However, for the purpose of developing the roadmap, the role of the EDB has been limited to its core function – providing a resilient electricity distribution service, such that electrical energy can be provided safely, reliably, efficiently and sustainably in the long-term interests of consumers.

The service is provided to consumers and electricity market participants on an equal access basis, locally and nationally. The roadmap does not attempt to identify or promote the commercial and entrepreneurial activities of EDBs – this is something for consideration by each EDB and is outside the scope of the roadmap.

The roadmap does not make recommendations as to how EDBs implement the roadmap. Actions can be carried out by each EDB individually, or collectively by groups of EDBs, or be provided by third party service providers. Work is already underway to develop a range of options to support EDBs in implementing the roadmap.

In developing this roadmap, similar roadmaps and consultations from other jurisdictions have been reviewed, with some aspects adapted for use in the scenarios that underpin this roadmap.

In particular these include the Australian Network Transformation Roadmap, the UK Electricity Network Association's consultation on open networks, and the Energy Networks Australia/Australian Energy Market Operator (AEMO) consultation on open energy networks.

These documents discuss several worlds or models for the future and introduce the concepts of distribution system operator (DSO), independent DSO, and independent market operator (IMO). This roadmap focuses on actions required of EDBs in the future, not industry structures and governance arrangements. Hence the need for a DSO, IMO, or some other organisation, is out of the roadmap's scope. Nevertheless, if one or more DSO were ever developed in New Zealand, actions in this roadmap would provide necessary support for their implementation.

The ENA has met with stakeholders throughout the NTR development. It has considered their views and numerous activities already underway in New Zealand, and it is intended that this roadmap will be regularly reviewed and updated.

A constant underlying all the scenarios that led to this roadmap is the requirement to meet climate change targets (such as the Paris agreement and net zero emissions by 2050) involving the need to decarbonise the economy.

In the scenarios, either renewable electricity or other renewable energy forms are used to achieve decarbonisation and thereby meet the climate change targets.

The roadmap aims to position EDBs to connect and supply renewable electricity to achieve decarbonisation.

A potential risk of not following the roadmap is reinforcing, or preferring, the outcomes in the 'backup-grid' (consumers remain connected to the grid for backup power, but use less energy from it, leading to lower EDB revenue) and 'leaving the grid' scenarios (consumers leave the grid completely).

1.2 Understanding the roadmap structure

Since the scenarios and the uncertainties they are built from are such an integral part of the NTR, Section 2 of this roadmap summarises the scenarios.

Section 3 introduces the roadmap structure and roadmap itself.

Section 4 provides greater detail of each roadmap programme.

Section 5 discusses the roadmap development methodology, and explains how the various programmes, and actions in each programme, were determined from input collected. It refers to a number of sections in the Appendix, which give details of the inputs to the roadmap.

A reader just wanting to understand the roadmap, need only read Sections 2 and 3. A reader wanting to both understand the roadmap and the detail of each roadmap action should read Sections 2, 3 and 4. A reader wanting to know why the roadmap is structured in the way it is, how the various actions were determined from the inputs, and why, should also read Section 5.

2

Network Transformation Roadmap Scenarios

The backdrop to all the scenarios is the need for New Zealand to meet its international climate change commitments, namely its Paris Agreement Nationally Determined Contribution by 2030 and net zero greenhouse gas emissions by 2050.

They show an opportunity for the electricity industry to contribute to these targets in New Zealand by 2030 and 2050. However, they also identify substantial challenges in achieving the targets with renewable electricity, in particular: the infrastructure development required; security of supply; regulation changes required; and transitioning energy end-use to renewable electricity. Such challenges raise the possibility of alternative ways of transitioning, such as biomass and alternative fuels for transport, heating, and on-site electricity generation such as hydrogen. Thus, there is a question over the extent of the electricity industry's contribution to greenhouse gas emissions reduction.

The scenarios also identify extremes of consumer behaviour:

- Passive consumers who focus on other things than electricity, and are therefore more reliant on the utilities who provide them with energy.
- Active consumers, or prosumers, who, through emerging technology, engage actively with their electricity supply and consumption or production, and new technology.

The resulting scenarios are described below and depicted in Figure 1.

Set and Forget: Passive consumers let the utility decide on their electricity supply based on their needs. Utilities and third parties assist consumers to transition to more renewable electricity use to meet their energy requirements. Central renewable electricity generation grows, with some growth in PV distributed generation. There is extensive EV uptake. The utility controls consumer load for the benefit of electricity supply, and most of the extensive battery deployment is in the distribution network. Load factor remains at about the same levels as a result of effective demand response and battery deployment.

Rise of the Prosumer: Through the use of technology, the prosumer actively decides on and changes their service level over time based on price. They actively provide demand response from load and batteries for a variety of services in the electricity supply chain, and gain reductions in cost as a result. Prosumers optimise their usage and on-site distributed generation, as well as sell it across the grid (distribution network and transmission network). There is extensive PV uptake and extensive EV uptake. Central renewable generation grows, and energy dense renewable fuels are used for storing energy between seasons. Through active demand response by consumers, and effective real-time signals by distributors, load factor on the distribution network remains high.

Backup Grid: Passive consumers allow third parties to manage their supply needs. A fragmented electricity industry provides more opportunity for third parties to enter the industry. This involves extensive on-site generation development (in particular PV) with batteries. Alternative renewable fuels are developed to supply the heating needs of residential, business and commercial consumers. Large co-generation schemes are developed by industrial consumers. Leaving the grid is neither an economic proposition nor a strong desire by consumers. Hence the grid becomes a backup supply. Load factor declines and per unit cost of supply increases.

Leaving the Grid: Disconnection from the grid becomes an economic possibility due to new renewable fuels for on-site use. Active consumers pursue this option, with the development of micro-grids or nano-grids such as communities and sub-divisions powered by local generation, which is effectively behind-the-meter.[1,2] Third parties actively manage the transition to alternative supplies for consumers. EV uptake is extensive with large central charging sites powered by renewable generation and batteries. Such sites include businesses, perhaps with their own distributed generation, that provide charging services for customers and staff. Load factor declines substantially and per unit price increases to a level where more consumers leave the grid. Substantial distrust of utilities fuels the desire to leave the grid.

1 A micro-grid refers to a collection of consumers still supplied by the distribution network, with distributed generation and storage batteries supplying load at times, but with a connection to the rest of the distribution network, which may be a lower capacity and/or lower reliability connection. This may be prevalent in the 'backup grid' scenario.

2 A nano-grid refers to a completely off-grid power supply (such as a combination of solar, storage battery, and generator) that supplies a small number of consumers, or a single consumer. A remote area power supply supplying a few consumers is an example of a nano-grid.

The scenarios and their development are discussed and presented in full in ENA's *Network Transformation Roadmap Scenarios* report. The primary megashifts and consumer behaviours that led to the four scenarios are shown in Figure 2.

Figure 1: Graphical representation of the scenarios.

Grid Supplied Renewable Energy	Consumer Behaviour: Passive — I care about my energy supply (active intervention) — Active
High	**Set and Forget** • Predominantly busy group of consumers. • An organised industry provides an array of solutions, with supply reliability managed and controlled by utilities. • Batteries are deployed in the distribution network, with grid connected technology to provide a resilient supply. • Renewable electricity is successfully positioned and used for greenhouse gas (GHG) reduction. Third parties manage the transition to electricity end use for consumers. • Central renewable electricity generation is high with extensive EV / autonomous EV uptake and moderate PV uptake. • Electricity is used for heating needs in homes, business and industry.	**Rise of the Prosumer (a.k.a. A Brave New World)** • Active prosumers push service providers for a rich array of solutions. • Well coordinated industry with extensive innovation and consumer participation. Third parties lead innovation. • Batteries deployed on-site, with consumers deciding on service level with use of technology and participating in managing the grid. • Renewable electricity used for GHG reduction. • Central renewable generation is high, with extensive PV development and EV / autonomous EV uptake. • PV uptake is also high, with excess used on-site or sold across the grid via peer-to-peer. • Electricity is used for heating in homes, business and industry. • Energy dense fuels are developed to store energy between seasons.
Low	**Backup Grid (a.k.a. Supplier of Last Resort)** • Busy consumers with little interest in electricity. • Uncoordinated industry solutions with little consumer engagement. • Technology deployment is sporadic, with third parties managing energy needs for consumers including some batteries behind the meter and on-site generation. • Utilities manage some demand response, others not at all. • Numerous other renewable fuels are developed for GHG reduction, leading to less demand for electricity. • These are used for home, business and industrial heating, with large co-generation and on-site generation development. • High EV / autonomous EV uptake.	**Leaving the Grid** • Consumers actively leave the grid for alternative supplies managed by non-traditional third parties. • Innovation occurs in other renewable fuels and off-grid power supplies. • These fuels are used to reduce GHG emissions. On-site PV and battery deployment is extensive. • EV / autonomous EV deployment is extensive, with charging at distributed large off-grid distributed generation (DG) sites. • Alternative fuels are used for home, business and industry heating, where co-generation is developed.

Figure 2: (a) All uncertainties, megashifts and consumer behaviours considered in adapting and developing the scenarios.

Uncertainties	Megashifts	Consumer Behaviour
Gas price and international methanol price	Low cost storage	Active-passive spectrum of consumer behaviour
Carbon price	Low demand for central electricity	Due to barriers to uptake, such as complexity and high price, consumers' actions are not always consistent with the values they express
Development of renewable energy-dense fuels	Consumer interest in PV and PV cost reductions	
Collective electricity industry contribution to greenhouse gas reduction	Greenhouse gas reduction	
Demand growth for centrally-generated electricity	Demand for greater reliability and services of electricity	
Regulation	Non-traditional third-party management of consumer needs	
Central generation costs	Consumer distrust of electricity utilities (where utility refers to the collective traditional electricity supply chain)	
Development of technology for consumer participation	EV uptake	
Autonomous EV deployment		
Economic management of renewable variability		
EV uptake		

Figure 2: (b) primary consumer behaviours and megashifts considered in adapting and developing the scenarios, which act as the keys and lead to the differences between each scenario.

Set & Forget	Rise of the Prosumer (Brave New World)
Consumer: Busy & therefore passive	**Consumer:** Actively engaged with electricity and suppliers, either directly or through technology
Reliability: Managed by utilities	**Reliability:** Managed largely by consumers, with industry management of long-term reliability
Third parties: Manage transition to end use of electricity for everything	**Third parties:** Lead innovation, especially in the consumer space, enabling consumers to participate in the market and manage their own reliability
Industry innovation: High	**Industry innovation:** High
Climate change obligations: Met with centrally supplied renewable electricity and some distributed generation	**Climate change obligations:** Met with centrally supplied renewable electricity and distributed
PV: Mainly used on site	**PV:** Used on site and traded across the network
EV Charging: Primarily on site at homes	**EV Charging:** Primarily on site or at businesses
Batteries: Mainly used in the distribution network, rather than behind the meter	**Batteries:** Primarily used behind the meter

Opposites

Backup Grid	Leaving the Grid
Consumer: Busy & therefore passive	**Consumer:** Actively engaged with electricity and suppliers, either directly or through technology
Reliability: Managed by utilities and third parties	**Reliability:** Managed entirely by consumers
Third parties: Manage energy needs of consumers	**Third parties:** Manage consumers off the grid and innovation to develop micro-grids
Industry innovation: Low	**Industry innovation:** Low
Climate change obligations: Mainly met with alternative renewable fuels such as biomass, bio fuels, hydrogen, with centrally supplied electricity, and electric vehicles charged with solar at large central charging sites or businesses. Substantial on-site generation and co-generation.	**Climate change obligations:** Met with alternative renewable fuels such as biomass, bio fuels, hydrogen, with centrally supplied electricity, and electric vehicles charged with solar at large central charging sites or businesses. Substantial on-site generation.
PV: Large on site and commercial	**PV:** Large on site and commercial
EV Charging: On site at homes and central charging stations	**EV Charging:** Primarily on site or at businesses with EVs becoming fuel transport mechanisms
Batteries: Used in both the distribution network and behind the meter	**Batteries:** Used on-site and behind the meter

3

Network Transformation Roadmap

3.1 Network Transformation Roadmap goals

The NTR goals, as established by the STWG at the outset of the NTR project, are listed below. The goals were devised by considering the core role of electricity distribution businesses (as set out in the Introduction), the desire of the regulators for more competition and participation by consumers in the electricity market, and meeting New Zealand's greenhouse gas reduction obligations. Furthermore, the goals were developed considering the purpose and scope of the roadmap (as discussed in the Introduction).

1. Enable the connection of new technology to electricity distribution networks in a sustainable way.
2. Inform new investment in, and management of, electricity distribution networks by developing a roadmap based on credible scenarios that the industry is able to use to make decisions (this includes informing the development of distribution services).
3. Improve the understanding of electricity distribution networks' role as a vital element within the electrical power system and wider economy, especially as electricity is being positioned to achieve New Zealand's climate change goals. Also, to inform stakeholders of the challenges EDBs face in ensuring a safe, reliable, efficient, and sustainable electricity distribution service as electricity is used in new ways – this explains the starting point of the roadmap.
4. Underpin the requirements that will enable market driven solutions and activities to occur between consumers and market participants (where possible preference is for this).

In essence, the NTR aims for an electricity distribution network where existing and new consumers are able to connect and operate any equipment they desire, with appropriate consideration of:

- Cost of access
- Network operation and system security for all users connected to the common network
- Standard equipment
- Access arrangements that are standard

The NTR also aims to enable the trading of energy and capacity between consumers and market participants using the distribution network.

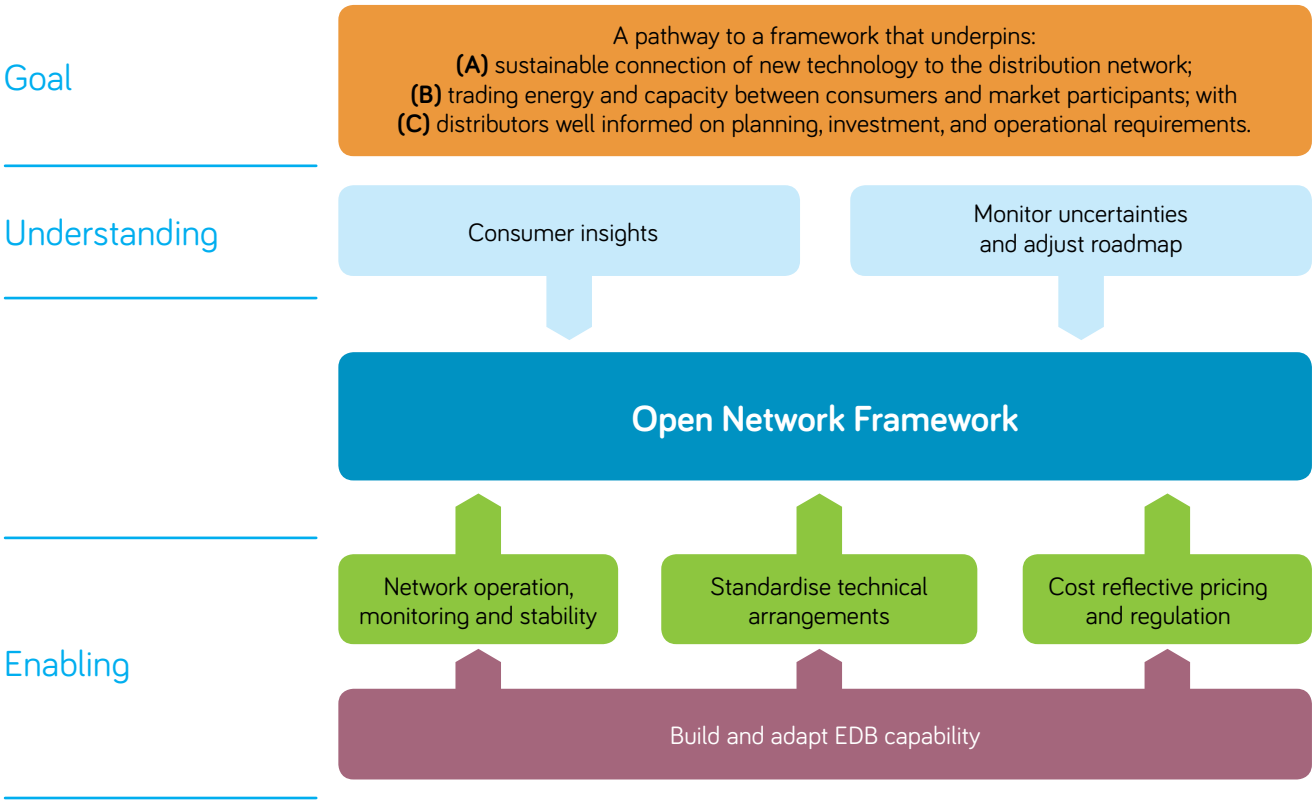
New equipment that consumers are expected to want to access the electricity distribution network with includes distributed energy resources (DERs) and new loads. DERs include PV, EVs, storage batteries, PV/battery control systems, home and business energy management systems (HEMS), and other new devices and/or control technologies yet to emerge. New loads include EV chargers, new types of lighting (such as LEDs), and electrification of heat. In this respect the underlying context of a renewable energy transition to meet climate change objectives in all scenarios that led to the NTR.

3.2 Network Transformation Roadmap structure

The NTR is depicted in Figure 3. At the centre of the roadmap is the Open Network Framework programme – the programme that realises the open network to which consumers can connect and operate any device, with appropriate consideration for cost of access, network operation, standard equipment, and standard access arrangements. This programme also realises the trading of electrical energy and capacity between consumers and market participants using the distribution network.

Six surrounding programmes either provide information to enable the Open Network Framework, or directly enable the Open Network Framework. The Open Network Framework programme and the six enabling programmes are briefly described in each of the following sub-sections. As discussed in the Introduction, more details about the actions, their timeline, and the background to the programmes are given in Section 4. Section 5 discusses the NTR development methodology, and inputs that led to the programmes and their actions.

Figure 3: NTR structure and relationship of programmes.



3.3 Consumer Insights

The Consumer Insights programme provides insight and support to the Open Network Framework through a deeper understanding of consumer behaviours and motivations. This understanding is particularly in relation to DER deployment, consumption patterns, and new load requirements. The programme comprises the following actions:

- Access to smart meter data

  Progressively over time address barriers to half-hourly consumption data to understand emerging behaviours, and ultimately be able to access sub half-hourly and power quality data

- Understand DER deployment

  Data on DER deployment (such as location, type, and size) available, moving to consumer understanding and scenario modelling to understand DER deployment possibilities.

- Understand new loads

  Start by understanding connection requirements (such as location, type, and size) of new loads, move to actively planning for and delivering network services to new loads.

- Understand new distributed generation (DG)

  Understand new DG connection requirements. Develop and trial new DG connection standards (for both small – and large-scale DG), and implement consistently across all EDBs.

3.4 Monitor Uncertainties and Adjust Roadmap

The objective of this programme is to stay abreast of technology developments and update the EDB industry as well as provide input to update the roadmap to remain relevant. The scenarios contained in ENA's *Network Transformation Roadmap Scenarios* report discussed a number of uncertainties, megashifts, and consumer behaviours that provide input to the scenarios, and in turn to the roadmap.

The uncertainties refer to aspects of the industry or new technology that are known, but which are uncertain. Examples include the carbon price, costs of central generation, EV uptake, and development of technology for consumer participation. Megashifts refer to major shifts in the industry that have

the potential to provide major disruption. Examples include consumer interest in PV combined with PV cost reductions, greenhouse gas reduction, consumer distrust of electricity utilities, and EV uptake. Consumer behaviours refer in particular to the active to passive spectrum of consumer behaviour.

The action in this programme is to monitor scenario and roadmap inputs, to lead to adjustments of the roadmap where there are significant changes. The process to achieve this and the full list of uncertainties to be monitored are discussed in Section 4.2.

3.5 Open Network Framework

As alluded to in Section 3.2, the objective of the Open Network Framework is:

- Access to the electricity distribution network by existing and new consumers and traders to connect and operate any equipment they desire (specifically DERs and new loads) with appropriate consideration of: (1) cost of access; (2) network operation and system security; (3) standard equipment; and (4) standard access arrangements.

While all other programmes in the NTR enable this objective, the Open Network Framework programme does have a number of actions itself:

- Enable distribution network trading

  Understand access requirements for DERs, open up access, and move to full and equal access to the distribution network as a vital platform for delivery of energy and capacity to and by consumers.[3]

- Third party DER and DR for network support

  Start by trialling DER and DR support and move to putting in place processes and systems for acquiring and using it, eventually moving to DER and DR being an important contributor to network operation and support.

- Demand response framework

  Work with regulators and the industry on the challenges of multiple users of DR – trial and move to full scale use of third party supplied DR to manage the distribution network.[4]

3.6 Cost Reflective Pricing and Regulation

Cost reflective pricing is an essential aspect of the Open Network Framework. It communicates the cost of using the distribution service for energy delivery, to and from prosumers, and of the need for capacity for network support. The NTR recognises the importance of providing cost-reflective, service-based, pricing of distribution services in order to ensure efficient and effective use of the distribution networks now and in the future. However, the ENA Distribution Pricing Working Group has been tasked with supporting EDB cross-industry efforts to reform pricing. Hence the NTR reflects the mandate that group has to lead this work.

3.7 Standardise Technical Arrangements

The objective of the Standardise Technical Arrangements programme is to:

- Provide a consistent method of connection of any equipment (DERs or appliances) across all EDB areas. Ensure equipment complies with approved standards to minimise its impact on the electrical power system.

It comprises the following actions:

1. DER connection codes

   EDBs jointly develop and implement new agreed connection frameworks/codes (referred to as *connection and operation standards* in the Electricity Industry Participation Code), moving to regular and consistent use by all EDBs, with consistency maintained across all EDBs.

2. Appliance and DER equipment standards

   EDBs collectively assess and contribute to international standards to ensure they are appropriate for NZ and adopt equipment standards appropriate to NZ. Test houses to approve equipment as compliant before being allowed on the network. All equipment connecting to the network is compliant to approved standards and codes, with consistency across all EDBs.

3. Network engineering

   Investigate how best to achieve consistent network engineering across all EDBs, trial, and practice.

3 The term 'platform' refers to a physical platform or system of some sort. It is only ever used in this roadmap in the Open Network Framework programme. Here it refers to the distribution network, as the physical system and predominant means by which traders buy and sell electrical energy, and capacity. A number of programmes support the platform, such as Build and Adapt EDB Capability through Action 3, improving the network understanding, and Network Operation, Monitoring, & Stability, through Action 1&2 LV network monitoring.

4 The term 'framework' refers to a set of rules, protocols, standards, codes, and/or guides that enable the activities discussed in this roadmap to take place. For example, the Open Network Framework enables traders to trade their energy and capacity across the distribution network, and even with the distribution network (demand response). Or EDBs access demand response from a platform using a framework. It is not a physical platform, but is invariably built on a physical platform. Much of this roadmap deals with what is required to deliver the framework of an Open Network and Demand Response. For example, Build and Adapt EDB Capability involves upskilling EDBs on contracting for network support (Action 2), which is a key part of the Open Network Framework, and the Standardise Technical Arrangements deals with development of codes, guides, and standards, which will contribute to the Open Network Framework. With regard to the demand response framework, it is likely that EDBs will contribute to a framework, rather than develop it themselves, since there will be other demand response users.

4. Cyber security and autonomous DERs

   Research appropriate cyber security standards and standards for autonomous DERs. Trial, and implement standards to ensure stability of autonomous DERs.

3.8 Network Operation, Monitoring, and Stability

The objective of the Network Operation, Monitoring, and Stability programme is:

- Ensure the stability of the open network through deeper monitoring of the network, and improved planning techniques.

It comprises the following actions:

1. LV network monitoring and visibility

   Roll out of LV monitoring systems with data management systems and provision of AMI data to assist with network management. Improve quality and type of monitored data over time. Lead to extensive knowledge of each LV network.

2. Network stability

   Research the implications of numerous autonomous DERs and methods of control. Trial control systems and implement control systems across EDBs (standardisation of these methods is covered in the Standardise Technical Arrangements programme).

3. Provision of network information

   Investigate the information required and trial provision of network information to operators, moving to regularly providing network information to operators, and eventually extensive provision of information.

3.9 Build and Adapt EDB Capability

The objective of the Build and Adapt EDB Capability programme is:

- Understand networks in greater depth, their ability to host DERs, congestion, and contracting for network support. Ensure working understanding of regulations and obligations of those.

It comprises the following actions:

1. Network understanding

   Understand congestion in LV networks (which may include medium voltage networks). Understand the ability of the LV network to host DERs, and opportunities for DERs to mitigate congestion.

2. Contracting for network support

   Trial framing of EDBs requirements for network support and introduce contestable procurement to discover a range of solutions. Develop the necessary processes to support contestable procurement of network support from trial experience. Move to regular practice, practiced consistently across all EDBs.

3. Asset management practice

   EDBs collectively explore, trial, and implement improved asset management practices and consistent frameworks across all EDBs.

4. Off grid power supplies

   Move from trialling remote area power supplies to best practice between EDBs, industry and consumers, practiced where it is more economic than traditional networks.

4

Detailed Network Transformation Roadmap Actions

This section discusses the roadmap programmes and actions in greater detail, and includes actions by timeframe. For example, certain immediate goals of each action are given in the two-year timeframe, medium-term goals in a two to five-year timeframe, and longer-term goals in a five to 10-year timeframe. The roadmap structure discussed at the beginning of Section 3.2 and given in Figure 3 provides the structure for the more detailed roadmap discussed in this section.

4.1 Consumer Insights

This programme is about using data and engagement with consumers to improve EDB insights into consumer needs to assist in network asset management – an opportunity identified from the scenarios. Consumer Insights is relevant to the Set and Forget and Rise of the Prosumer scenarios through understanding the electrification needs and reliability needs of consumers.

It is also relevant in understanding consumer needs in relation to remote area power supplies or micro-grids – hence it is relevant to the Leaving the Grid scenario.

The consumer insights referred to are intended for network purposes, including:

- To understand where possible congestion may be occurring, or likely to occur in the future; and
- Understanding how the network is used, to allow development of improved asset management approaches.

Central to all programmes, the Consumer Insights roadmap is shown in Figure 4.

Figure 4: Consumer Insights roadmap of actions versus time.

Objective: Understand consumer motivations and behaviours to determine: (1) the impact on DER deployment and consumption patterns; and (2) new load requirements.			
Actions	2 years	2–5 years	5–10 years
1. Access to smart meter data	Addressing barriers to access half-hourly consumption data	Provision of half-hourly consumption data to understand emerging behaviours	Access to sub half-hourly consumption data to develop deeper understanding, access to power quality data where such meters installed
2. Understand DER deployment	Develop requirements to access data for all DER types	Data for all DER types being gathered and analysed	Scenario modelling across the entire network is commonplace to consider DER deployment possibilities
Note: there is synergy between 'Consumer Insights' and 'Network Monitoring, Operation, and Stability' Programmes			
3a. Understand new loads	EDBs connecting new load types or converted loads	EDBs are able to plan their network to be able to connect future new loads	EDBs actively delivering new network services to new loads
3b. Understand new DG	Develop and trial consistent DG connection approach and connection and operation standard for small and large scale DG. Designed to collate information on new small and large scale DG	Implemented and practicing DG connection approach and connection and operation standards for small and large scale DG. Potential DG connections are understood.	Consistency in DG connection between all EDBs. Potential DG connections are well understood, analysed and managed consistently across all EDBs

4.2 Monitor Uncertainties and Adjust Roadmap

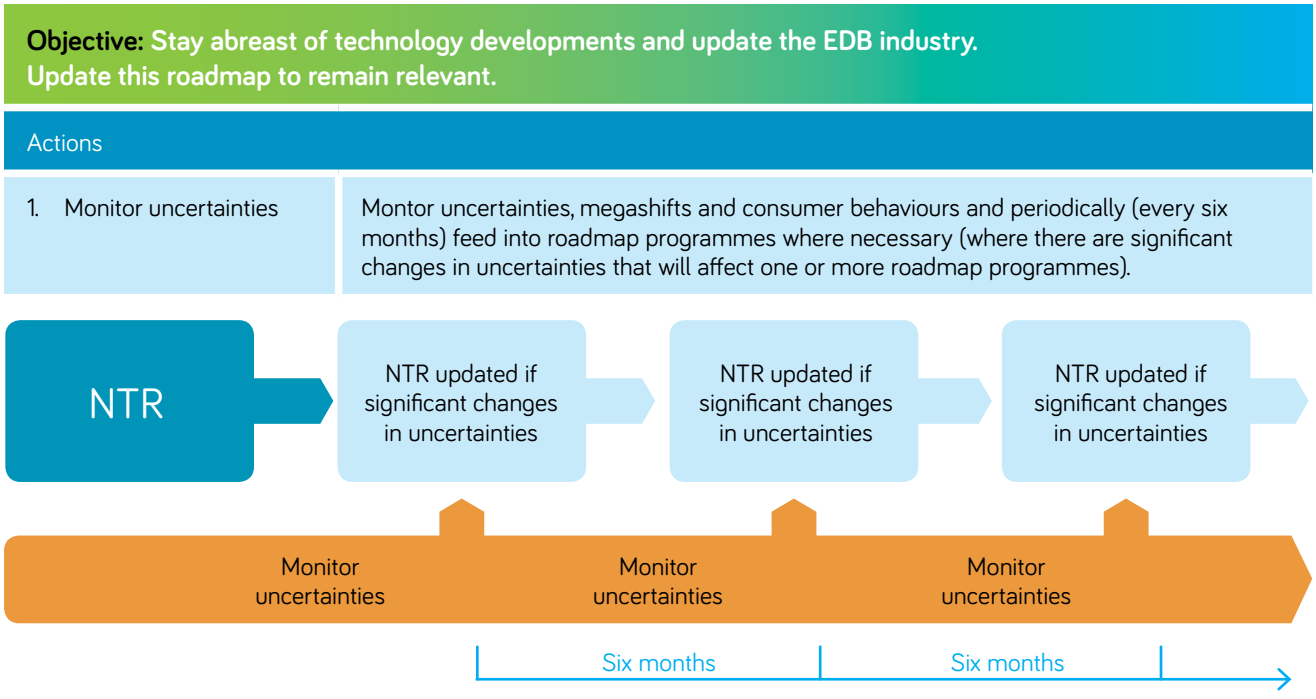
The purpose of this is to consider and make changes to the roadmap where significant changes in uncertainties will affect one or more roadmap programmes. Examples include new types of DERs or consumer energy uses, and emerging patterns of DER uptake.

The full list of uncertainties to be monitored, based on those introduced in ENA's *Network Transformation Roadmap Scenarios* report, is given below (with Section numbers referring to relevant sections in that report, or marked with an '*' where they are additional at the suggestion of the STWG), while the process to monitor the uncertainties and update the roadmap is depicted in Figure 5.

- Development of renewable energy-dense fuels for on-site and central generation use (from Section 4.1). This should include hydrogen.
- Central generation costs (Section 4.1).
- Development of industrial process heat electrical technology and fuels (Section 4.1).
- PV and energy storage prices and uptake for any increase in uptake (Section 4.5).
- PV and energy storage uptake in each distribution area (Section 4.5).

- Clustering of PV and energy storage (Section 4.5).
  - Advances in production solar technology (Section 4.5).
  - Battery (and other emerging forms of energy storage) prices for actual changes (Section 4.6).
  - Updated EDGS scenarios be re-examined when they are available in late 2018 or 2019, and that actual energy consumption and peak demand be tracked for trends (Section 4.7).
  - Monitor major changes, up or down, in immigration for its impact on electricity demand (Section 4.19).
  - Changes in agricultural practices over the next 10 years during the implementation of the NTR. This is for the impacts they may have on electricity demand, greenhouse gas reduction, and opportunities for further electrification and fossil fuel replacement. (Section 4.19).
- Business model digitisation and cyber security threats for any impact on EDBs ability to deliver their service (Section 4.19).
- Electric vehicle technology uptake, including by area, to understand overall uptake, and any clustering of uptake (Section 4.19).
- Electric vehicle technology as an input that could lead to substantial change in electricity consumption patterns (Section 4.19).
- Space and hot-water heating technologies.*
- Distribution LRMC by location.*
- Cost for equivalent reliability of alternative means of supplying renewable / competitive forms of renewable energy.*
- Monitor development of smart metering technology, communications infrastructure, data volumes, storage, and data access capabilities.*

Figure 5: Monitor uncertainties action.



4.3 Open Network Framework

The Open Network Framework provides an electricity distribution network which existing and new consumers are able to access and operate any equipment they desire, such as DERs and new loads, with appropriate consideration of cost of access, network operation, and standard equipment and access arrangements. It enables the trading of electrical energy and capacity using the distribution network, which may also involve the DERs.

It addresses all scenarios, recognises the opportunity presented by the Rise of the Prosumer scenario, and arose out of stakeholder conversations and consideration of other inputs to the roadmap. It also recognises this as:

- an opportunity for EDBs (electricity as a lifeline infrastructure) from the scenarios;
- use of DERs including DR to manage network size;
- managing the load profile to a more desirable one;
- and better cost reflective pricing to better represent the cost of providing the distribution network).

Many of the actions required to achieve the Open Network Framework are in later roadmap programmes – thus they are enabling programmes. The Open Network Framework roadmap is shown in Figure 6.

Figure 6: Open Network Framework roadmap.

Objective: Access to the electricity distribution network by existing and new consumers and traders to connect and operate any equipment they desire (specifically DERs and new loads) with appropriate consideration of: (1) cost of access; (2) network operation and system security; (3) standard equipment; and (4) standard access arrangements.

Actions	2 years	2–5 years	5–10 years
1. Enable distribution Network Trading	Consulting on access requirements to the distribution network for delivery of energy from alternative source and trading of energy and capacity. This will involve engaging with regulators and their consultations	Distribution network starts to open up as a stable, effective platform for delivery of energy and trading of alternative energy from producer to consumer	Full and equal access to the distribution network as a vital platform for delivery of energy and trading of alternative energy from producer to consumer
2. Third parties provide DERs and DR for network support	Trialling DERs in certain constrained areas for network support	Process and systems in place to consider DERs and DR for network support	DER and DR use fundamentally changes network operation and support
3. Demand response framework	Challenges of multiple users of demand response understood, transition plan under development	Trialling multiple users of demand response; incorporating home and business automation; developing experience into standards/codes	Starting full scale use of third party supplied demand response including coordination with other DR users

4.4 Cost Reflective Pricing and Regulation

The Cost Reflective Pricing and Regulation programme arises from how to price the Open Network Framework for trading and better reflection of the cost of providing the distribution network service. It arises from the need for cost reflective pricing to ensure efficient Rise of the Prosumer (provision of services in real-time) and Set and Forget scenarios, and the Backup Grid scenario (how such a scenario might become self-fulfilling without appropriate pricing).

This programme recognises the current ENA Distribution Pricing Working Group activities and Electricity Authority pricing workstream, as well as the ENA Regulatory Working Group.

4.5 Standardise Technical Arrangements

This programme arose from stakeholder briefings and from STWG input, where the need for consistency across EDBs was made clear. It relates to a more self-governing industry with respect to standards, codes, and guides, and more control over what standards to adopt for New Zealand, and what aspects of those standards are mandatory when connecting equipment to New Zealand's electricity distribution network. As part of a self-governing industry, EDBs adopt the same standards, use the same codes and implementation of guides, and in turn present the same 'interface' to network users.

A further action here is network engineering, achieving consistent network engineering practice across all EDBs.

The Standardise Technical Arrangements roadmap is shown in Figure 7.

Figure 7: Standardise technical arrangements roadmap.

Objective: Provide consistent method of connection of any equipment (DERs or appliances) across all EDB areas. Ensure equipment complies with approved standards to minimise its impact on the electrical power system.

Actions	2 years	2–5 years	5–10 years
1. DER Connection Standards	Developing and implementing new connection standards and frameworks/codes derived from this roadmap for DERs	All EDBs regularly use 'the' connection standards and codes for DERs	Connection standards and codes for DERs evolved by EDBs, with consistency maintained between all EDBs
2. Appliance and DER equipment standards	Distribution industry group set up to assess and contribute to international equipment standards to ensure they are appropriate to NZ	Standards appropriate to NZ, with test houses to approve equipment as compliant before being allowed on the network. Consistency across all EDBs	All equipment connecting to the network is compliant to the approved standards with enforcement for breaches
3. Network engineering	Investigate how best to achieve consistent network engineering	Trialling consistent network engineering across EDBs	Practising consistent network engineering across all EDBs
4. Cyber security and autonomous DERs	Research appropriate cyber security standards and standards for autonomous DERs	Research and trial implementation of new cyber security standards and contribute to autonomous DER standards	Implementation of new cyber security standards and standards to ensure stability of autonomous DERs

4.6 Network Operation, Monitoring, and Stability

The Network Operation, Monitoring, and Stability programme partially originates from EDB concerns with many autonomous DERs acting together, which may lead to instabilities or new load peaks, and the cyber security risk from numerous internet aware devices controlling network load. It is also closely related to aspects of Standardise Technical Arrangements, which is more about standardising findings from this programme.

The roadmap for this programme, depicted in Figure 8, is increasingly important as more DERs connect to the electricity distribution network, and as EDBs increasingly use DERs and DR as a means of improving quality of supply and managing load factor, but also as DERs may potentially degrade quality of supply and network loading.

Figure 8: Network operation, monitoring, and stability roadmap.

Objective: Ensure the stability of the open network through deeper monitoring of the network and improved planning techniques.

Actions	2 years	2–5 years	5–10 years
1&2. LV network monitoring & visibility	Actively rolling out LV monitoring systems with data management systems Provision of available AMI operational data to assist network management	Improve quality of LV monitored data and AMI data. New indices (data types) added. E.g. move from just voltage levels to energy and power flows, and eventually other voltage quality metrics and harmonics	Extensive knowledge of LV network and analysis tools AMI capability able to meet operational requirements for network management, provided in real-time
3&4. Network stability	Researching the implications of numerous autonomous DERs and methods of control to ensure stability and avoid new load peaks	Trialling control systems for numerous autonomous DERs to ensure stability and avoid new load peaks	Implementing control systems for autonomous DERs
5. Provision of network information	Investigating and trialling provision of network information to operator(s)	Provision of available network information to operator(s)	Provision of extensive network information to operator(s)

4.7 Build and Adapt EDB Capability

This programme is primarily about understanding the capacity of the electricity distribution network to host DERs, understanding congestion DERs may cause, and seeking solutions to congestion from non-traditional network solutions (such as from DERs and/or DR).

Since DERs are connecting predominantly to the LV network, it entails greater understanding of those networks, their DER hosting capacity, and congestion state of networks.

To alleviate congestion, building the expertise to seek solutions from the market is part of this programme. As such it is an important enabler of the Open Network Framework.

Finally, this programme entails building expertise with off grid power supplies, for network areas where it is more economic to serve consumers with remote area power supplies, or possibly micro-grids, than it is to serve consumers with traditional network solutions. This programme deals to some extent with the technical 'know how' of remote area power supplies, but in particular it addresses the expertise required in dealing with consumers, retailers, regulators and others to manage the transition to remotely powered, isolated, grids. This is more about an aspect that hasn't been practiced extensively in New Zealand, or elsewhere, to date, of confidently managing the consumer from one paradigm to another, as well as working through the regulatory aspects and with incumbent retailer(s).

The Build and Adapt EDB Capability roadmap is shown in Figure 9.

Figure 9: Build and adapt EDB capability roadmap.

Objective: Understand networks in greater depth, their ability to host DERs, congestion, and contracting for network support. Ensure working understanding of regulations and obligations of those.

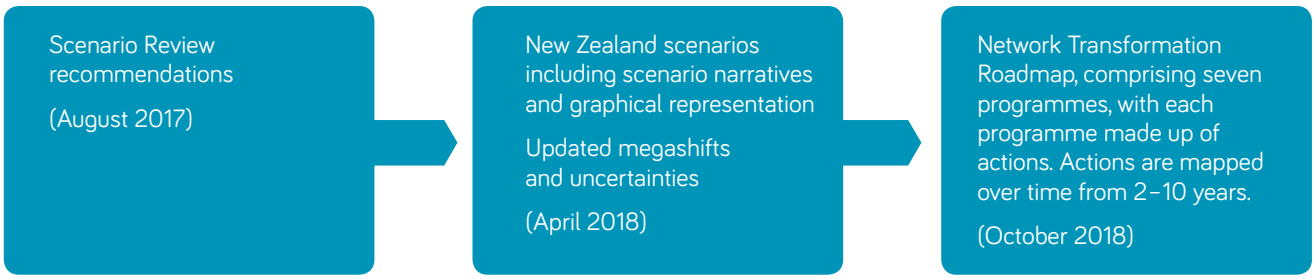
Actions	2 years	2–5 years	5–10 years
1. Network understanding	Starting to understand LV network capabilities, performance and constraints	Most EDBs are starting to collect extensive data about their LV networks and their operation	All EDBs have comprehensive LV network condition, performance, and utilisation data with models of the combined LV and MV networks
2. Develop contracting for network support capabilities to support Action 2 of the Open Network Framework	Trial framing of EDBs requirements for network support and introduce contestable procurement to discover a range of solutions	Develop the necessary processes and systems for contestable procurement of network support from trial experience	Consistent practice of open procurement for network support, practiced consistently across all EDBs
3. Asset Management practice	EDB industry exploring improved asset management practices and consistent frameworks	Improving asset management practice across most EDBs, with regular information sharing	Mature asset management and systems engineering practiced consistently across all EDBs
4. Off grid power supplies	Trial remote area power supplies	Implement remote area power supplies in areas where it is less costly than traditional networks	Consistent best practice agreed between EDBs and other industry participants, and practiced extensively

5

Roadmap Development Methodology and Detail

This section discusses the methodology used to develop the roadmap and summarises inputs to the roadmap. It also refers to a number of sections in the Appendix, which give details of the inputs to the roadmap. The overarching roadmap development process is depicted in Figure 10, which draws on the Scenario Review carried out by ENA prior to the commencement of the NTR project, and is based on the scenarios documented in ENA's *Network Transformation Roadmap Scenarios* report, which also discusses the process used to develop the scenarios.

Figure 10: Overarching roadmap development process.



The decision to review international scenarios, and adapt them, was made to avoid a large programme of work, and in consideration of substantial activities and research already carried out in New Zealand. The previous and existing activities and research are documented in ENA's *Network Transformation Roadmap Scenarios* report.

The process used to develop the scenarios into the NTR is described in Section 5.1.

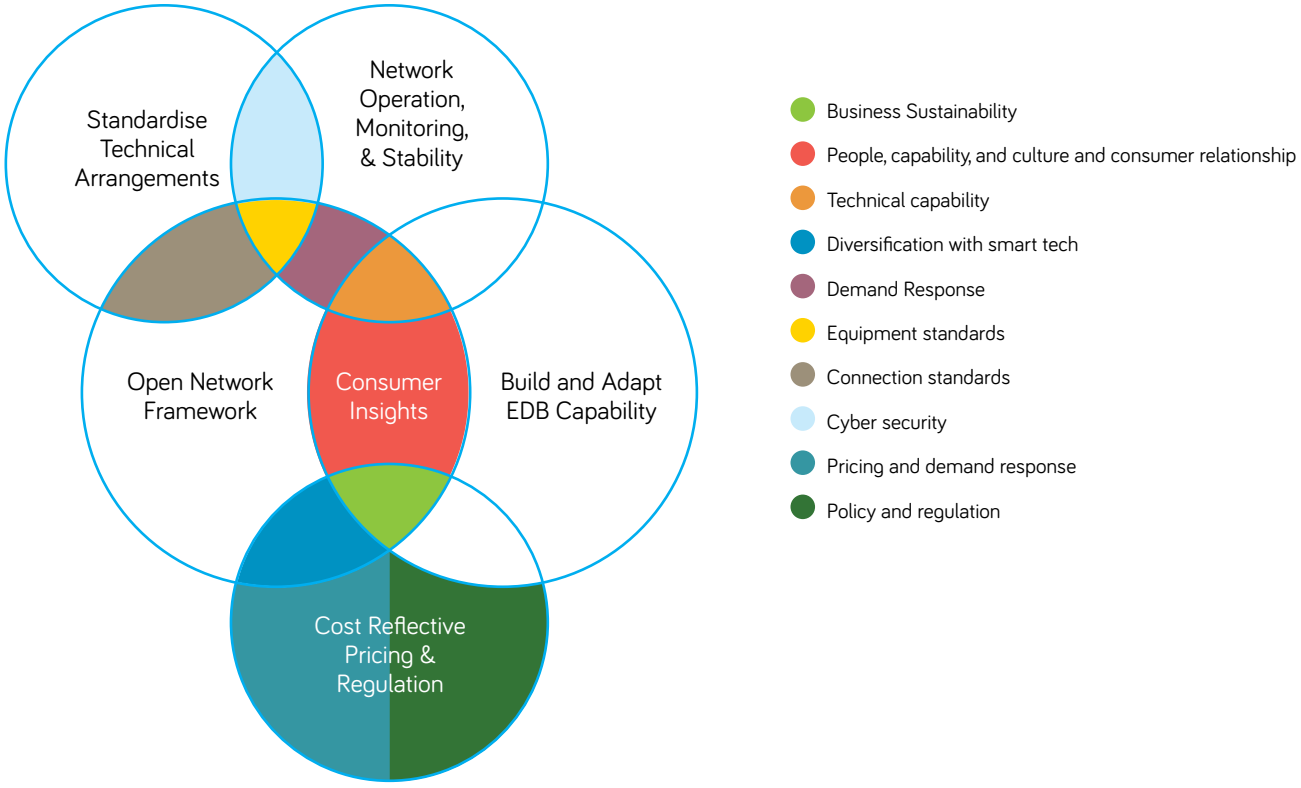
5.1 Methodology

At the start of the NTR development, the project set out to develop plausible scenarios to 2050. These are documented in detail in ENA's *Network Transformation Roadmap Scenarios* report and are summarised briefly in Section 2. A methodology outlined below was devised to transform the scenarios, and other external input, into the roadmap.

1. Consider the 2050 scenarios.
2. The STWG considers the scenarios in terms of: (1) the current internal, organisational, ability of EDBs to meet any of these futures (summarised as strengths and weaknesses); and (2) how the external environment inherent in each scenario will affect EDBs (summarised as opportunities and threats). The output of this analysis is summarised in the following sub-section.
3. EDBs and Stakeholders consider the 2050 scenarios, with results combined with Step 2, as follows:
    a. Obtain direct EDB input, potentially from all EDBs, using a questionnaire, and combine the results with step 2. The EDB questionnaire and its results are summarised in the Appendix, Section 7.2.
    b. Obtain direct stakeholder input and combine the results with Step 2. Stakeholder input was obtained from direct meetings with stakeholders, and review of stakeholder output such as the Electricity Authority's workplan, Commerce Commission material, and the Electricity Authority's Innovation and Participation Advisory Group (IPAG) minutes. The stakeholder input is summarised in the Appendix, Section 7.3, while Section 7.4 summarises other input.

4. Group each output from Steps 2 & 3 by function and combine functions to a minimal list.[5] The functions determined are:
    i. Business Sustainability[6]
    ii. People capability & culture
    iii. Technical capability
    iv. Demand response from traditional appliances and/or DERs
    v. Diversification with smart tech
    vi. Pricing and demand response
    vii. Policy and regulation
    viii. Connection standards
    ix. Equipment standards
    x. Cyber security
    xi. Consumer relationship
5. Within each function, gather the outputs from Steps 2 and 3 together, ensuring that all are considered.
6. From the output of Step 5, devise *actions* to address any barriers or weaknesses identified from Steps 2 and 3, and to utilise any opportunities or strengths identified from Steps 2 and 3. When devising actions, consider the future uncertainty represented by the scenarios, elements that are common to the scenarios, and therefore what actions would best address those elements and thereby give 'least regrets' actions. In some cases an element may be unique to a particular scenario, but an action still be devised to address that.
7. Rationalise the actions into programmes, with detailed *actions* in each programme. Link programmes to the scenarios and provide narrative on transformation from Steps 2 and 3 to each programme. The programmes form the overarching roadmap structure. Figure 11 shows how the programmes fit together, and where they share the functions identified at Step 4.
8. Make actions more granular, over a phased timeline, to show steps over time to achieve the full action. This provides the actual roadmap within each programme, as shown in Section 4.

Figure 11: Relationships between the programmes and the functions identified in Step 4 above.



5 Some outputs from Step 2 were reclassified – for example, what was originally listed as a strength may in fact have related to something external to the EDB and more appropriately be listed as an opportunity.

6 Business sustainability combines: business sustainability, business growth, cost management, cherry picking, network utilisation, and reliability.

5.2 Detailed data collected and mapping to roadmap programmes and actions

Figure 12 to Figure 17 show the condensed raw input from Steps 2 and 3, summarised by function (Steps 4 and 5), linked to actions devised in Step 6, and grouped by programme (Step 7). The actual actions arrived at in Step 6 were initially drafted in August 2018. STWG feedback was then obtained in a series of iterations to provide the final actions, programmes, and their order (Steps 6 and 7), and the actions broken into timelines. This was completed in in October 2018. During the STWG process described, the scenarios were maintained as the backdrop, to represent the uncertainty of the future, and a 'least regrets' focus on actions was maintained.

As discussed earlier, in each of Figure 12 to Figure 17 the process of transforming the original inputs to the actions involved an initial classification of the inputs, formation into functions, and several iterations of review by the STWG to devise the actions in the form shown in these figures. Direct EDB inputs from the questionnaire are shown separately, with the sub-section of the questionnaire referred to in parentheses.

Figure 12: Actions grouped into the ***Consumer Insights*** programme: Summarised inputs (left) and relationships to the actions (right), with actions devised to address the issues and opportunities identified by the inputs.

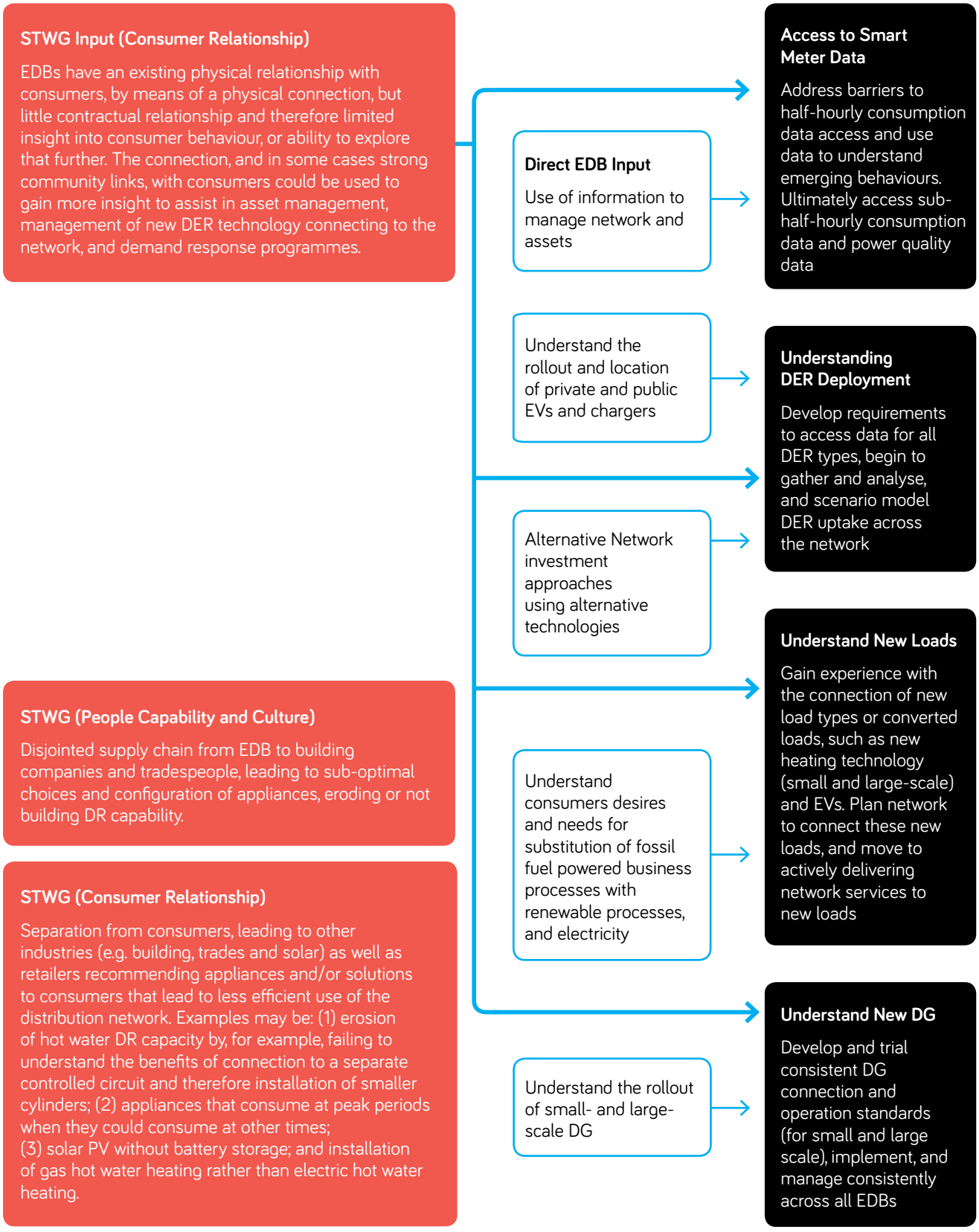


Figure 13: Actions grouped into the ***Open Network Framework*** programme: original inputs (left) and relationships to the actions (right), with actions devised to address the issues and opportunities identified by the inputs.

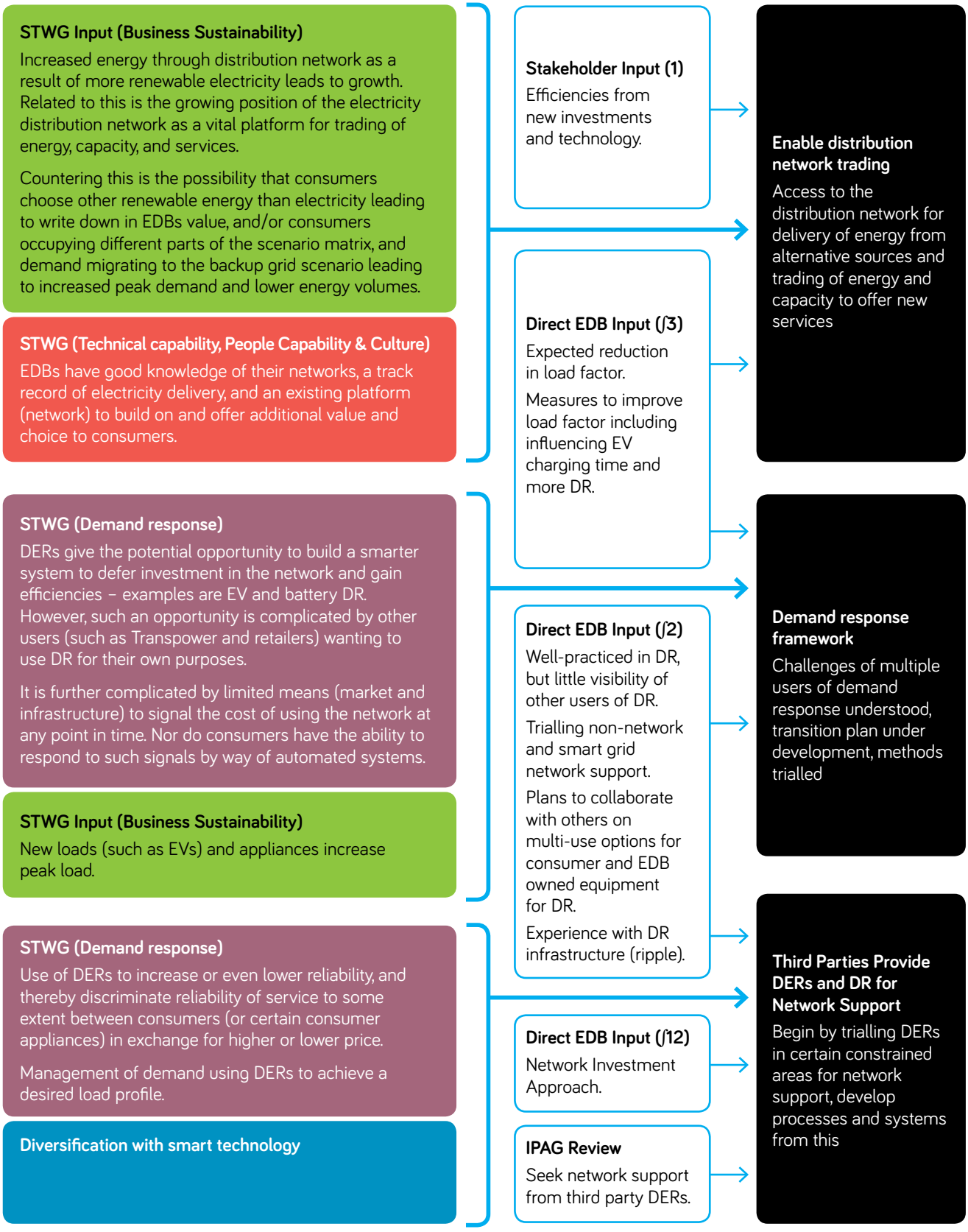


Figure 14: Original inputs (left) that are grouped into the ***Cost Reflective Pricing and Regulation programme***. Specific actions were not determined; instead the inputs provide input to the ENA's DPWG and RWG, which will themselves devise actions.

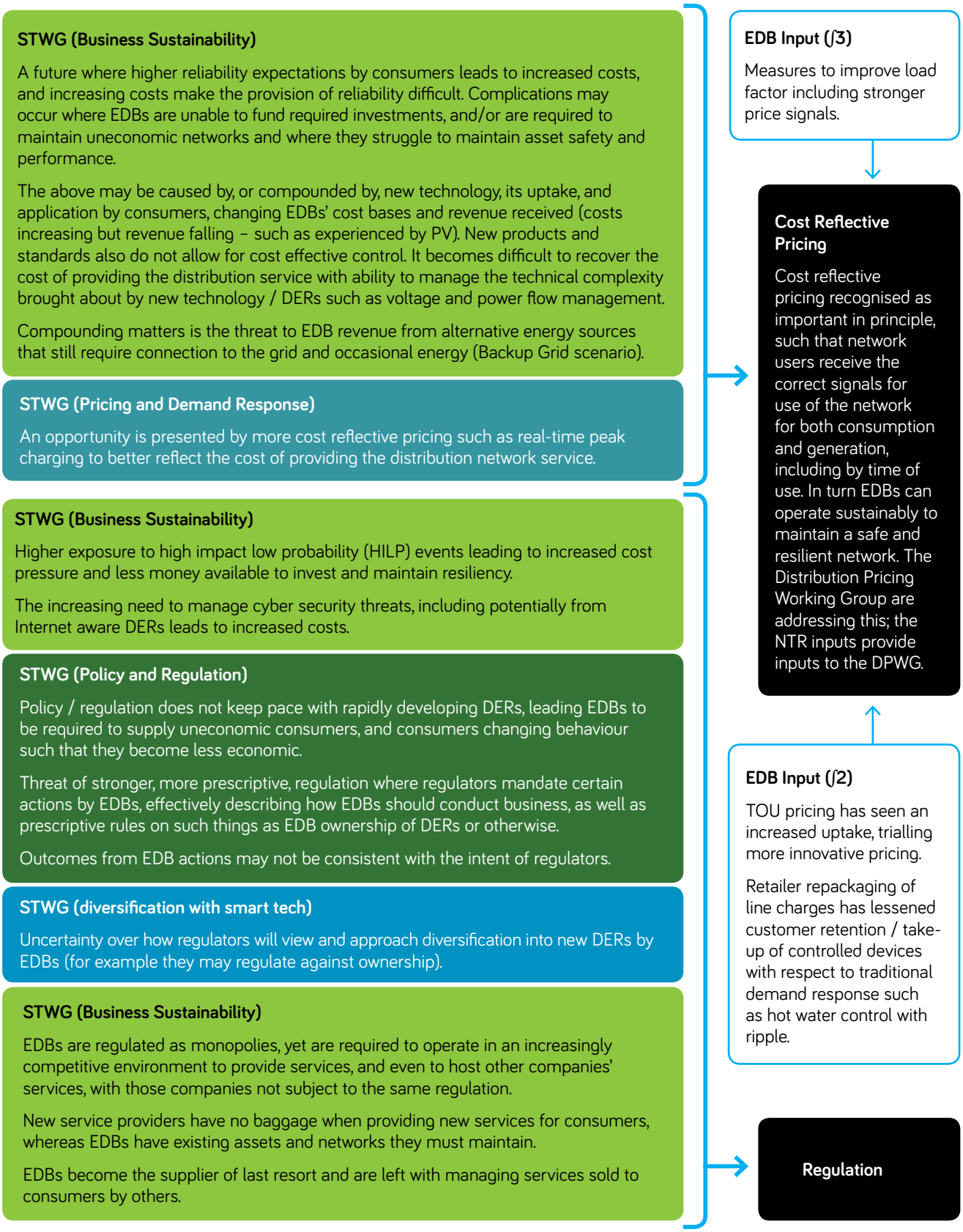


Figure 15: Actions grouped into the ***Standardise Technical Arrangements*** programme. Original inputs (left) and relationships to the actions (right), with actions devised to address the issues and opportunities identified by the inputs.

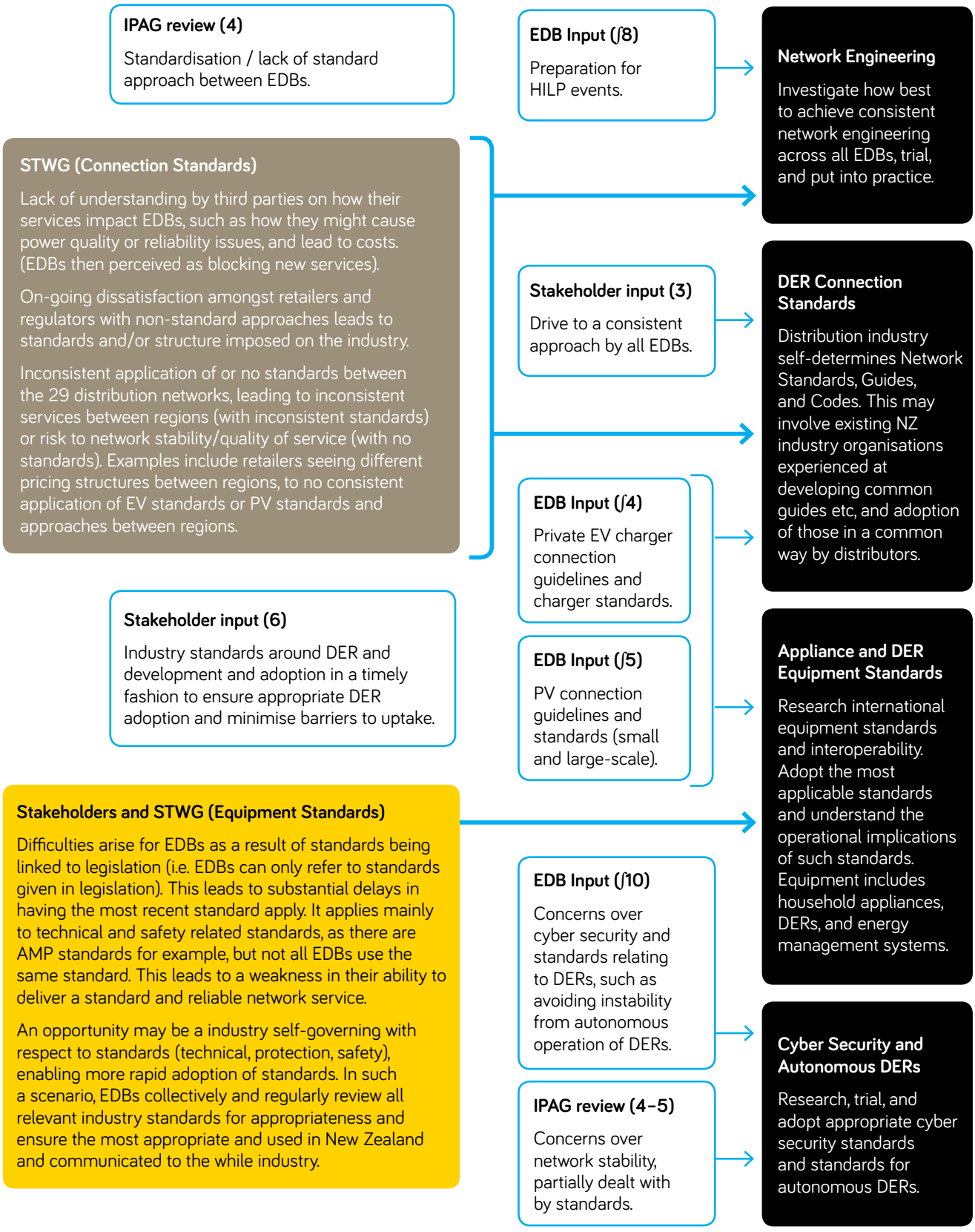


Figure 16: Actions grouped into the ***Network Operation, Monitoring and Stability*** programme. Original inputs (left) and relationships to the actions (right), with actions devised to address the issues and opportunities identified by the inputs.

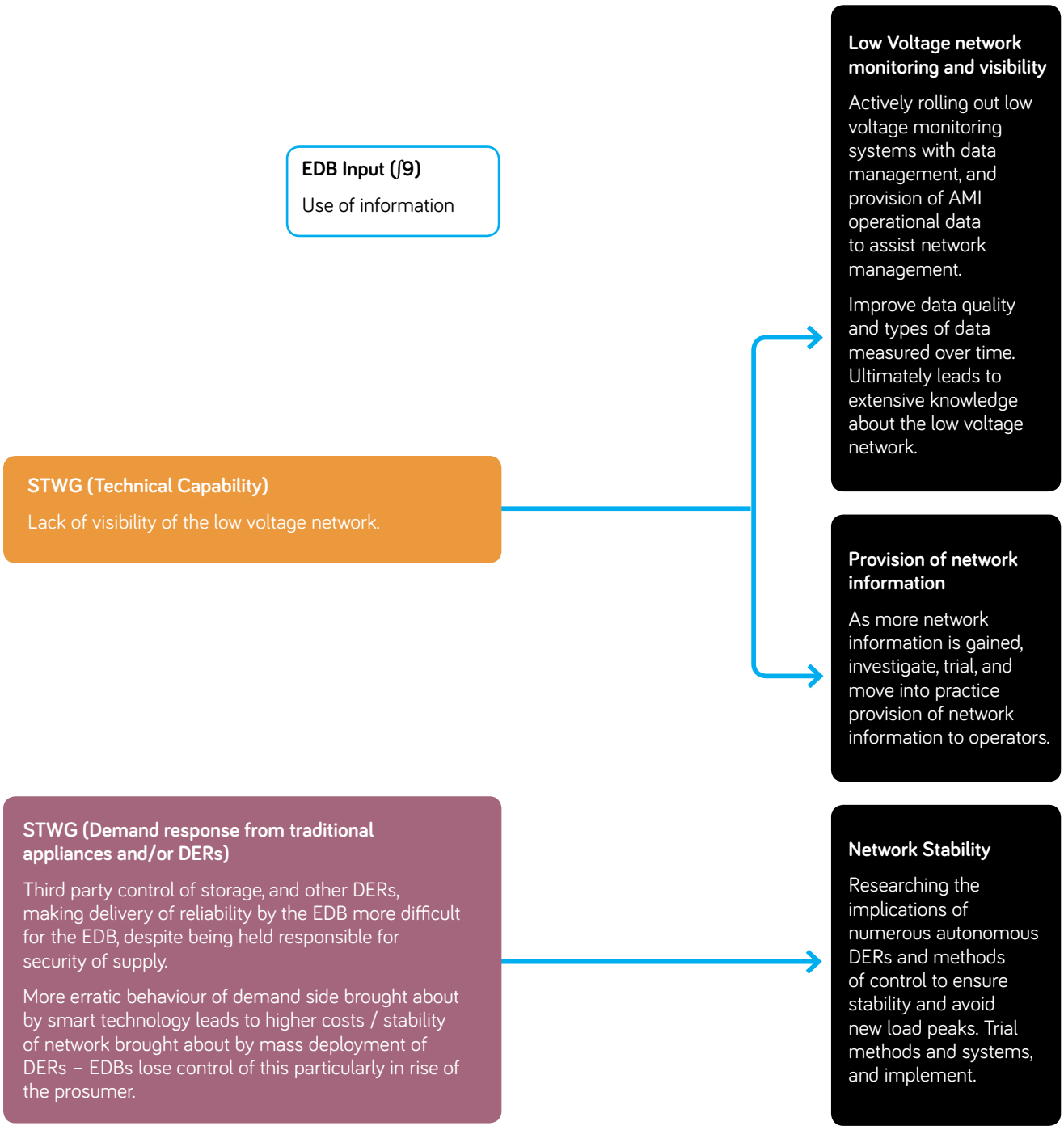
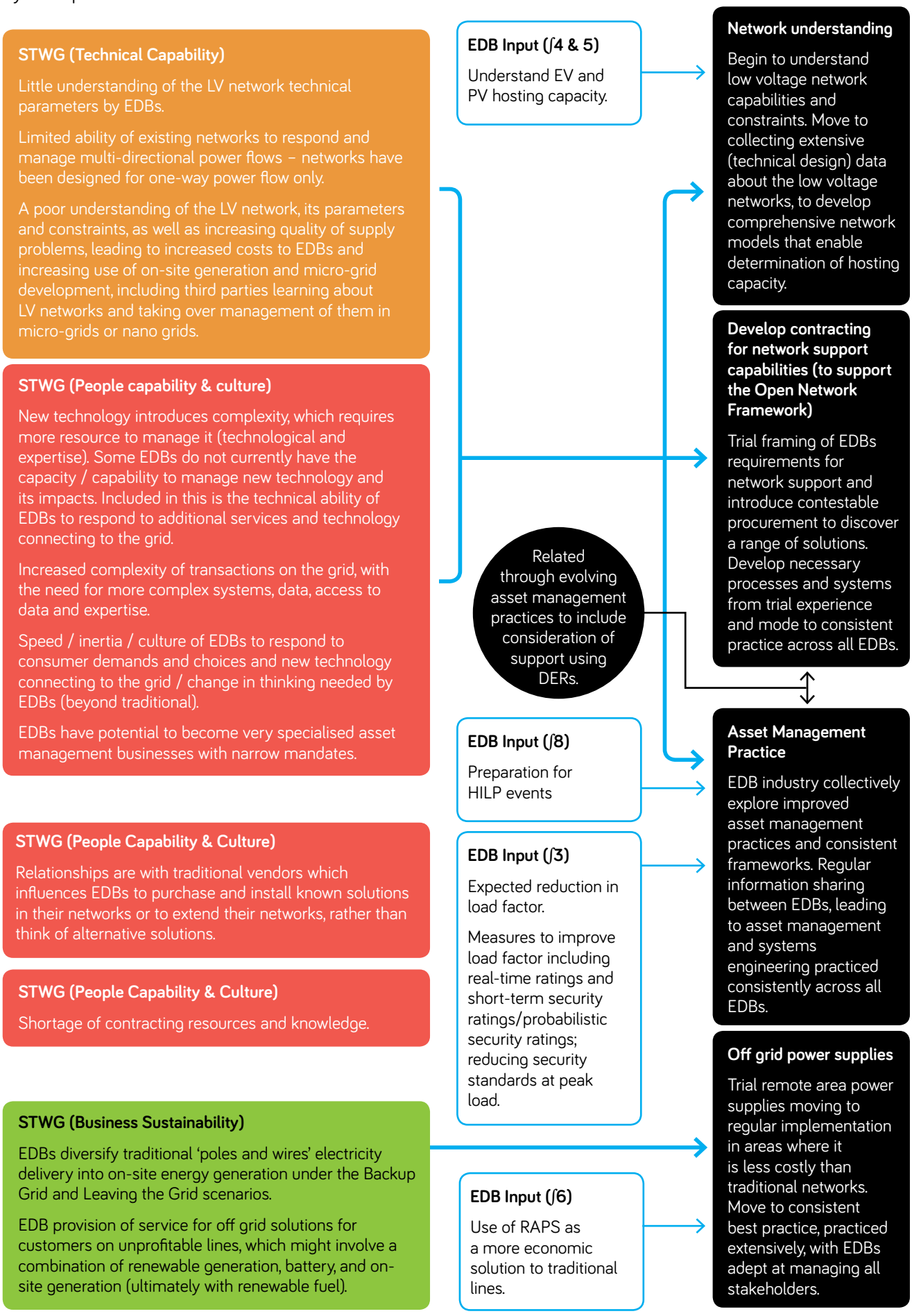


Figure 17: Actioned grouped into the ***Build and Adapt EDB Capability*** programme. Original inputs (left) and relationships to the actions (right), with actions devised to address the issues and opportunities identified by the inputs.



6 Appendix

6.1 STWG workshop to consider scenarios

The results of the STWG workshop held in June 2018 to consider the scenarios are covered in Sub-section 5.2, Figure 12 to Figure 17.

6.2 EDB questionnaire

A survey of EDBs was made in April 2018. The questionnaire was provided to all EDBs. This sub-section provides an aggregated summary of the responses received. The results are summarised below, and represented on each of Figure 12 to Figure 17.

6.2.1 The purpose of an EDB

Sustainability and *safe supply* were consistently ranked as fundamental to the purpose of an EDB[7] (score for sustainability: 100%, and for safe supply: 96%). Close behind sustainability was resilience (score of 83%).[8] Some way behind resilience were reliable supply and efficient supply (score of 67% each).[9]

These provide context to the NTR and informed the direction of the programmes.

6.2.2 Consumer control and engagement, and equal access

Responses showed a mix of maturity with consumers assisting with management of the EDB's network (such as avoiding congestion and/or deferring investment), ranging from not practiced at all, to trial and early stages, to well developed and mature. The main way in which consumers assist is with management of residential hot water with ripple control and larger consumer demand response. It was noted that there is little visibility of other users of demand response, but that some EDBs have plans to collaborate with other consumers and others over multi-use options for consumer owned equipment and are already trialling these. These contribute to the *Demand Response Framework* and *Third parties provide DERs and DR for network support* action of the Open Network Framework.

A number of EDBs are trialling time of use and more innovative pricing, although some note that retailer repackaging of line charges has lessened customer retention / take-up of controlled devices with respect to traditional demand response such as hot water control with ripple. These contribute to the *Cost Reflective Pricing* action of the *Cost Reflective Pricing and Regulation* programme.

6.2.3 Network utilisation and demand response

Responses showed that all EDB respondents are well practiced in maintaining load factor/network utilisation, but that without further measures to maintain network utilisation it is expected to degrade. The main reasons given for expected degradation were EV charging coincident with the evening peak, reduction in discretionary load in peak periods, and PV reducing energy but not peak load.

Planned approaches to maintain or improve load factor involve: influencing EV charging times; DR, batteries, and increasingly strong price signals; a focus on peak load reduction; real-time ratings and short-term security ratings/probabilistic security ratings; reducing security standards at peak load; and battery and new hot water load control trials.

These contribute to Enable Distribution Network Trading (for the trading of capacity) and Demand Response Framework (for the acquisition of demand response in coordination with other demand response users) of the Open Network Framework programme.

They also contribute to the Cost Reflective Pricing action of the Cost Reflective Pricing and Regulation programme (for the price signals to obtain demand response) and to Asset Management Practice action of the Build and Adapt EDB Capability Programme (for the relatively new ways of managing assets).

6.2.4 Electric Vehicles

All EDB respondents are intending to understand the ability of their networks to host EVs, or are practicing this already. This provides an input to Network Understanding actions of the Build and Adapt EDB Capability programme, through understanding LV networks' capacity to host EVs.

Introduction of guidelines for private EV chargers is being considered by some EDBs, but is in early stages. There are a range of approaches to this, including in-house, a national

7 Sustainability refers to the operation of the business in a way that is sustainable and thus able to operate into the future. Safe supply refers to the delivery or provision of electricity such that lives and property are not put at risk.

8 Resilience refers to the capacity of an EDB and its assets to withstand disruption and restore supply rapidly, be that from a natural disaster, change in business environment, change in the use of electricity or changes in technology connecting to the grid, now and in the future.

9 Reliability refers to the delivery or provision of electricity with minimal or no interruption to supply, and must consider the cost of providing the electricity distribution service and consumer preferences for reliability. Efficiently refers to cost effectiveness and minimal losses in the delivery or provision of electricity.

development, looking to industry bodies (such as the EEA), and looking at best practice internationally. Thus, this contributes to the DER Connection Standards and Appliance and DER Equipment Standards actions of the Standardise Technical Arrangements programme.

This is also an input to the Understand DER Deployment and Understand New Loads actions of the Consumer Insights Programme, since the location of EV chargers is necessary for hosting capacity analysis, and is an action oriented toward increasing the uptake of EVs, and thereby converting more loads to (renewable) electricity.

6.2.5 Distributed generation

All EDB respondents are intending to understand the ability of their networks to host PV, or are practicing this already. This provides an input to Network Understanding actions of the Build and Adapt EDB Capability programme, through understanding LV networks' capacity to host PV.

The introduction of guidelines for PV features in all EDBs' strategies or plans, although not all EDBs plan to use the EEA's guideline (currently a draft guideline awaiting the introduction of hosting capacity to the Electricity Industry Participation Code (EIPC)). This is possibly because not all EDBs are aware of the EEA's guide. This contributes to the DER Connection Standards and Appliance and DER Equipment Standards actions of the Standardise Technical Arrangements programme.

It also contributes to the Understand DER Deployment and Understand New DG actions of the Consumer Insights Programme, since these are necessary to estimate hosting capacity and to integrate more distributed renewable generation.

In all of these, larger scale DG should also be considered, not just small-scale DG.

6.2.6 Micro-grids and off-grid power supplies

All EDBs are considering use of remote area power supplies (RAPS), with most actively planning for their use or practicing. The main reason is a more economic solution to traditional lines in some areas or to deal with particularly peaky loads. Technology used is solar, battery, gen-set, and large-scale battery for peaky loads. This contributes to the Off-grid Power Supplies action of the Build and Adapt EDB Capability programme.

6.2.7 Substitution of fossil fuel powered business processes

Half the EDB respondents have no plans to supply business consumers with electricity as an alternative to fossil fuels. Of the other half they are either planning for this, just embarking on it, or practicing it. In any case this contributes to the Understand New Loads action of the Consumer Insights programme. Working with consumers to address their environmental wishes is only in the strategy stages of EDB respondents at present.

6.2.8 Resilience to natural events/disasters

Most EDB respondents are starting to plan for increasing frequency and/or severity of disruptions from natural events, or are actively preparing for it. Events include earthquakes, extreme weather, impact of extreme weather increasing, coastal storms, increasing wind speeds, low lying flooding. A number of methods are being considered to maintain reliability, such as more network meshing, mobile generators, DG, automated switching, targeting exposed areas for upgrade or replacement, monitoring, and increased wind loading.

These provide input to the Network Engineering action of the Standardise Technical Arrangements programme, through sharing of methods across all EDBs, and the Asset Management action of the Build and Adapt EDB Capability programme.

6.2.9 Use of information

Most EDB respondents are practiced in using information to manage their networks and assets. Others are planning for this or embarking on practicing it. Information includes visibility on network out to the edges, asset condition, access to metering and LV data, IoT sensors, drones and LIDAR. This contributes to the Low Voltage Network Monitoring and Visibility action of the Network Operation, Monitoring, and Stability programme. It also contributes to the Access to Smart Meter Data action of the Consumer Insights programme.

6.2.10 Cyber security

The majority of EDB respondents are actively practicing protection from cyber security threats. Specific information on expected threats and measures to protect businesses is excluded for confidentiality reasons. This contributes to the Cyber Security and Autonomous DERs action of the Standardise Technical Arrangements programme.

6.2.11 Approach to planning for the future

All EDB respondents are changing the way they plan for the future. Scenarios feature strongly with sensitivities. Formal network evolution strategies also feature.

6.2.12 Network investment approach

All EDB respondents have changed their approach to investing in traditional network assets. They are considering alternative technologies including batteries, DG, and other DERs. They are also considering greater customer engagement and utilising smarter distribution technology.

This provides input to the Third Parties Provide DERs and DR for Network Support action of the Open Network Framework and to the Understand DER Deployment, Understand New Loads, and Understand Distributed Generation actions of the Consumer Insights programme.

6.2.13 Consumer engagement

All EDB respondents are undertaking to inform business strategy through understanding customer expectations. To date they are employing routine surveys and formal customer advisory boards. This provides input to the Consumer Insights programme.

6.3 Stakeholder meetings

Stakeholder meetings were held separately with the following groups:

- The Commerce Commission
- The Electricity Authority
- Major Electricity Users Group
- The Electricity Retailers Association
- MBIE Energy Policy
- Consultants to the electricity industry
- The EEA
- Transpower
- Academics and researchers

A summary of stakeholder input is given below, with contributions to the various actions and programmes given.

1. **What efficiencies will consumers get from new investments; in all other jurisdictions new technology has driven efficiencies?**

   In response to this question consideration was given to writing the roadmap in such a way that the electricity distribution service allows consumers to access new technologies and the multiple benefits those technologies they can provide. The benefits include efficient delivery of the distribution service such that costs do not escalate, the use of DERs as part of the service delivery, and access to other markets with the DERs. Such initiatives also consider other activities in the industry such as the Electricity Authority's work plan.

   This consideration, with other inputs, led to the Open Network Framework programme, through the need for use of smart technology to defer network investment (the Third Parties Provide DERs and DR for Network Support and Enable Distribution Network Trading actions), as shown in Section 4.3.

2. **What will be the cross over to the ENA pricing working group and initiatives?**

   Cost reflective distribution pricing is an action in the roadmap, which recognises the activity already underway by the DPWG.

3. **Retailers are seeing different approaches by EDBs to a common problem, which imposes costs on retailers.**

   This feedback has led to a need for strong roadmap programmes that drive to a consistent approach, specifically standardisation in certain areas. It is reflected in the Standardise Technical Arrangements programme.

4. **The scenarios and/or roadmap might be useful in reconciling how prepared each EDB is, as a benchmark.**

   This is not the primary purpose of the roadmap. The main reason for the roadmap is as a tool to aid EDBs navigate to the future.

5. **Stakeholders were interested in the uncertainty of future technology and uptake and how the NTR will account for that.**

   This is incorporated in the Monitor Uncertainties and Adjust Roadmap programme.

6. **Stakeholders were interested in standards in the industry around DERs and how they might be developed and adopted in a timely fashion to ensure appropriate DER adoption and minimise barriers to uptake.**

   This is incorporated in the Standardise Technical Arrangements programme.

7. **What is the 'grid' in the context of the scenarios?**

   While intended to be the generic distribution and transmission grid in the scenarios, this question suggested care should be taken when referring to the grid in the NTR. Where necessary the LV and/or MV networks are specifically referred to.

8. **To what extent is the NTR an asset management plan?**

   The NTR informs asset management plans (AMPs), but it is not an AMP itself. For example, a programme in the NTR may focus on the use of DERs to delay or avoid traditional network reinforcement, which will then feed into the AMP.

9. **What will the level of detail of the NTR programmes be?**

   Not so detailed as to provide specific instructions to EDBs, rather detailed enough for EDBs to adapt as they see fit for their businesses.

6.4 Other input

6.4.1 IPAG

Given the cross-over between the IPAG's Equal Access project and the NTR, the IPAG's available minutes were summarised as input to the NTR. A brief summary of available IPAG minutes to 14 June 2018 and interpretation of them is given below.

1. In terms of what changes EDBs might expect in the future, and the roadmap, it is assumed that there will be increased requirement on EDBs to seek to procure network support from third parties through contestable means, rather than: (a) traditional network reinforcement solutions; and (b) solely developing the DER solutions themselves.
2. Whether there will be changes to the EIPC to require this remains to be seen; at the 14 June 2018 meeting the Commerce Commission discussed Part 4 of the Commerce Act 1986 and noted that, amongst other things, *"Distributors have incentives to: discover solutions imposing the least cost on consumers"*. From this it is interpreted that EDBs already have an obligation to procure network support services from DERs under a contestable framework, if that imposes the least cost on consumers.
3. It was noted by the IPAG (14 June minutes) that: *"reasons why distributors may not consider procuring, or be able to procure, network support services from third parties, such as the need for network support (e.g. demand response) often being specific to a location and existing for a limited time period, and distributors being financially responsible for security of supply; consequently, it may be very difficult for a distributor to procure network support services at a specific location with confidence to know they will be able to continue to supply consumers"*.
4. The IPAG has touched on standardisation / lack of standard approach between EDBs, and standards as a way of dealing with many autonomous devices acting at once.
5. Expert advice was sought on network operation implications of many diverse users, with discussions ongoing. The autonomous operation of many DERs is clearly a concern, including the possibility of new network peaks emerging as they all respond to the same input, such as price, as is the need for some sort of control of them in rare cases where they must be activated to ensure supply reliability.

ena
electricity networks association

Level 5, Legal House
101 Lambton Quay, Wellington 6011
PO Box 1017, Wellington 6140
New Zealand
+64 4 471 1335
electricity.org.nz