Energy Networks Australia

CSIRO

ELECTRICITY NETWORK TRANSFORMATION ROADMAP: FINAL REPORT

2017-27

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A partnership between Energy Networks Australia and CSIRO

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Electricity Network Transformation Roadmap publications can be downloaded from www.energynetworks.com.au/roadmap

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EXECUTIVE SUMMARY

Transformation on an unprecedented scale

The electricity system supporting Australia's modern economy and lifestyle is experiencing change on an unprecedented scale. The transformation is driven by customers as they embrace new technologies, take control of their energy use and support action on climate change. By 2050, it is estimated that customers or their agents - not utilities - will determine how over $200 billion in system expenditure is spent and millions of customer owned generators will supply 30-45% of Australia's electricity needs.

In a decentralised yet integrated energy future, electricity networks must be responsive to the changing demands for traditional services while enabling new opportunities for energy resource sharing and balancing. By connecting millions of customer owned generators and energy storage systems to each other, networks can act as platforms which help match supply and demand and reduce the need for inefficient duplication of energy investments. Large scale variable renewable energy can also be effectively integrated into the grid with the prospect of Australia's electricity sector achieving zero net carbon emissions by 2050.

Navigating to a customer oriented future

A future where up to 45% of all electricity is generated by customers in 2050 – at the opposite end of the system from its original design – presents a very significant range of technical, economic and regulatory challenges.

CSIRO modelling indicates that almost $1,000 billion[i] could be spent by all parties in Australia's electricity system by 2050, however, the benefits achieved will depend greatly on decisions made early in our energy transition. Without a well planned approach to navigate this transformation, Australia's energy system will be unable to efficiently and securely integrate the diverse technologies, large scale variable renewable energy sources and customer owned distributed energy resources. This will potentially result in the costly duplication of energy investments.

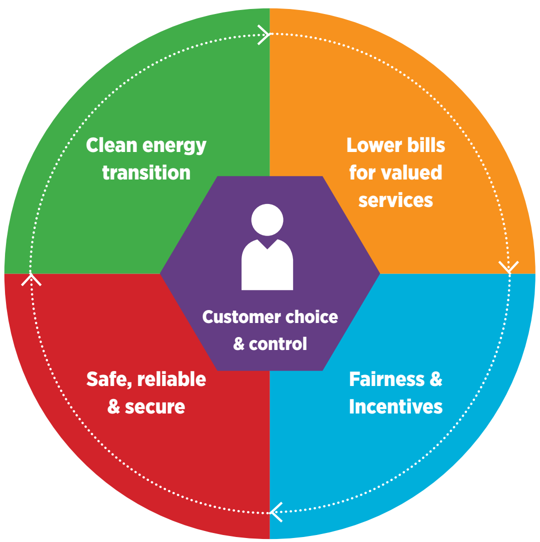
The *Electricity Network Transformation Roadmap (the Roadmap)* has been developed to provide detailed milestones and actions to guide an efficient and timely transformation over the 2017-27 decade. Developed by Australia's national science agency CSIRO and Energy Networks Australia, *the Roadmap* is informed by an evidence based approach, referencing over nineteen reports that summarise expert analyses, scenario analyses and quantitative modelling to 2050. An integrated set of 'no regrets' actions are identified to enable balanced, long term outcomes for customers, enable the maximum value of customer distributed energy resources and position Australia's networks for resilience in uncertain and divergent futures.

i See electricity system total expenditure, page 9

Balancing diverse customer needs

A customer oriented transformation of a complex and essential energy system requires several high-level objectives to be balanced simultaneously. The 'Balanced Scorecard of Customer Outcomes' (Figure i) has guided *the Roadmap's* development to serve diverse customer interests. For example, Australia's electricity system must seek to achieve decarbonisation at least cost to customers without jeopardising power system security. Equally, it must incentivise and enable new customer choice and control, while providing appropriate customer protections and avoiding unfair impacts on vulnerable customers.

Figure i: Balanced Scorecard of Customer Outcomes



The critical role of the integrated grid

The 2017-27 decade is likely to see a step change in the adoption of new technologies, including distributed energy resources such as rooftop solar, energy storage and electric vehicles. With falling technology costs and carbon abatement targets, the next decade offers a limited window of opportunity to reposition the electricity system to achieve balanced long term customer outcomes.

The full value of millions of customer owned distributed energy resources can only be realised in a connected future that enables multi-directional exchanges of energy, information and value. This is because the networking of energy resources enables *individual* customer benefits in exchange for services that help optimise the system which benefits *all customers*. This co-optimisation allows future network investments in 'poles and wires' to be lower than otherwise anticipated, even as more value is created on smarter electricity network platforms.

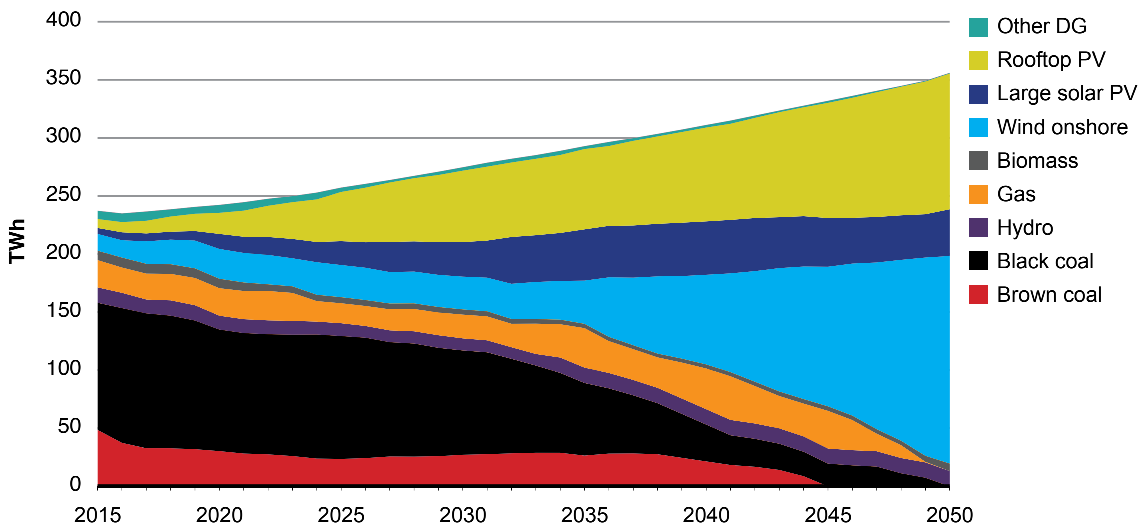
However, timely action is required. The agility with which networks can connect, integrate and incentivise new, lower carbon energy choices will directly influence the cost, fairness, security and reliability of customer outcomes. Urgent regulatory and policy changes will be needed to retain power system security, while saving customers money through efficient use of distributed energy resources, standalone systems and micro-grids. The timely development of technical standards and new information platforms will be required to animate new distributed energy resources markets and support enhanced customer services.

Power system security in a zero net emissions future

The Roadmap analysis supports the potential for a zero net emissions objective to be pursued. Transformation of the transmission network is proposed to ensure that it can facilitate the transition to a low emission generation future while delivering high levels of energy security and reliability.

Energy system modelling undertaken for *the Roadmap* identified the generation mix in Figure ii as a plausible projection for meeting wholesale energy requirements and achieving zero net emissions by 2050. The analysis assumes a primary role for storage in balancing the output of variable renewable energy (VRE). While battery storage was selected as a plausible new source of balancing energy, there are a diversity of potential solutions which could be employed and these are recommended for further study.

Figure ii: Plausible projection of Australia's changing energy mix to 2050



The transmission network plays a critical role by allowing a diverse and dispersed resources mix to provide a highly reliable energy balance for a wide range of operating conditions. It will also play a key role by ensuring that power system security can be retained in a system with much lower levels of system inertia.

There are a range of technical solutions to achieve inertia and frequency management outcomes. For example, these include the use of synchronous condensers, large scale batteries, flywheel technology and emulated inertial responses from wind farms. Additionally, the distribution system is also a potential source of new ancillary services to support transmission-level system stability as discussed in Section 9.

The Roadmap includes a recommendation to carry out detailed power system security analysis for a system with very low levels of native inertia to address system stability and security risks. This work program will provide a detailed specification for the transmission system, including the connected equipment and controls, to achieve high levels of system security for a zero net emissions future.

Purpose and structure of this document

A structured, evidence based roadmap developed in consultation with a wide range of stakeholders, provides the best opportunity for Australia to navigate this complex transformation. With the right balance of elements, Australia's electricity sector can exceed current abatement targets, 'keep the lights on' and deliver lower costs to Australian households and enterprise.

The purpose of this *Roadmap Report* is to provide stakeholders with an overview of key content developed through the detailed research and engagement phases of *the Roadmap* program.

The document commences by outlining the approach that has been applied to program modelling and benefits evaluation. It then provides an overview of five key domains which function together as an ecosystem of societal, technological, economic and regulatory sub-systems.

Supported by specific chapter content, these domains are:

» Customer oriented electricity

» Power system security

» Carbon abatement

» Incentives and network regulation

» Intelligent networks and markets

Each section includes:

» a statement for a *2027 Resilient Future State*

» an outline of research findings

» a set of integrated milestones for navigating the 2017-27 decade

The relationship between each of the milestones and their enabling actions is then illustrated in a roadmap diagram specific to each chapter.

A Transformed Electricity System by 2050

» Customers retain security and reliability essential to lifestyle and employment

» Networks pay distributed energy resources customers over $2.5 billion per annum for grid support services by 2050

» Electricity sector achieves zero net emissions by 2050

» $16 billion in network infrastructure investment is avoided by orchestration of distributed energy resources

» Reduction in cumulative total expenditure of $101 billion by 2050

» Network charges 30% lower than 2016

» $414 annual saving in average household electricity bills (compared with roadmap counterfactual, business as usual, pathway)

» A medium family who cannot take up distributed energy resources is over $600 p.a. better off (in real terms) through removal of cross subsidies

Overview of *the Roadmap*

	FOUNDATION (2017, 2018, 2019, 2020, 2021, 2022)	IMPLEMENTATION (2023, 2024, 2025, 2026, 2027, 2027+)
CUSTOMER ORIENTED ELECTRICITY	**Improve trust with customers** through better engagement, customised services and reform of customer protection frameworks.	**Networks provide a service platform** that is responsive to the changing needs of diverse customers and which provides open information stimulating new market innovation.
POWER SYSTEM SECURITY	**Implement new frameworks and services for achieving system security** with diverse generation and energy technologies and retain focus on physical and cyber security.	**Enhanced system operations at all voltage** levels, as transmission networks offer additional services and distribution networks provide visibility of resources and other services.
CARBON ABATEMENT	**Secure a stable carbon policy** including a trading scheme for generator emissions, enabled by agile network connection and integration of large and small technologies.	**Review scope for consensus on more efficient carbon pricing**, refocus technology specific schemes and increase the Australian international emissions reduction target (2027)[ii].
INCENTIVES & NETWORK REGULATION	**Incentivise efficiency and innovation** through: implementing fair and efficient demand based network tariffs; enabling standalone systems and micro-grids, and; modernising regulation and competition frameworks.	**Transform efficiency of energy delivery with orchestration of distributed energy resources** as networks pay for support in the 'right place at right time' including use of stand alone systems and customer focussed regulation.
INTELLIGENT NETWORKS & MARKETS	**Develop essential information tools for a cost effective integrated grid**, including: open standards, extended monitoring, advanced planning and feeder hosting analysis, and the mapping and locational valuation of distributed energy resources.	**Establish active distribution system operations and markets** for technical stability and optimising investment by procuring distributed energy resource based grid support. Evaluate cost benefit analysis of procuring these services through a digital market platform.

Overall Customer outcomes by

	2027	2050
CUSTOMER CHOICE AND CONTROL	» Over 40% customers use onsite resources: 29 GW solar and 34 GWh of batteries. » Concessions to support those who need it most.	» Almost 2/3 customers use onsite resources, including 1/3 customers on a new stand alone system tariff.
LOWER BILLS FOR VALUED SERVICES	» Avoid over $1.4 BN in network investment. » Average network bills 10% lower than 2016.	» Total system spend is $101BN lower to 2050. » Save households $414 pa by 2050. » Network charges 30% lower than 2016.
FAIRNESS & INCENTIVES	» Networks pay over $1.1 BN pa for DER services. » Over $1.4 BN in cross subsidies avoided, saving $350 pa for med size family without DER.	» Networks pay over $2.5 BN pa for DER services. » Over $18 BN in cross subsidies avoided, saving $600 pa for med size family without DER.
SAFETY, SECURITY, RELIABILITY	» Planned and efficient market response avoids security & stability risks. » Robust physical & cyber security management.	» Real time balancing, reliability and quality of supply at small and large scale, with millions of market participants.
CLEAN ENERGY TRANSITION	» Electricity sector carbon abatement to reach 40% by 2030 – greater than current national target of 26-28%.	» Electricity sector achieves zero net emissions by 2050.

ii COP 21, Paris Agreement, Intended Nationally Determined Contribution

CONTENTS

1. INTRODUCTION

Background

The Electricity Network Transformation Roadmap (*the Roadmap)* has been developed as a partnership between Australia's national science agency CSIRO and Australia's electricity networks, represented by Energy Networks Australia. *The Roadmap* was initated recognising that:

- » Australia's electricity networks are facing complex challenges that impact the economic efficiency and technical stability of the system;
- » Australia's electricity system will require expenditure of almost $1000 billion by current service providers, new entrants and customers by 2050; and,
- » The type and scale of benefits gained from this unprecedented investment will vary greatly depending on decisions made early in this period and particularly during the decade from 2017-27.

The scale of the transformation is illustrated by scenario based modelling that identifies the possibility that up to 45% of Australia's electricity supply could be provided by millions of distributed, privately owned generators in 2050. Along with significant opportunities, this provides profound adaptation challenges for the system's architecture, stability and efficiency given it was originally designed for almost 100% of generation at the transmission end of the system.

A Balanced Scorecard for Customer Outcomes

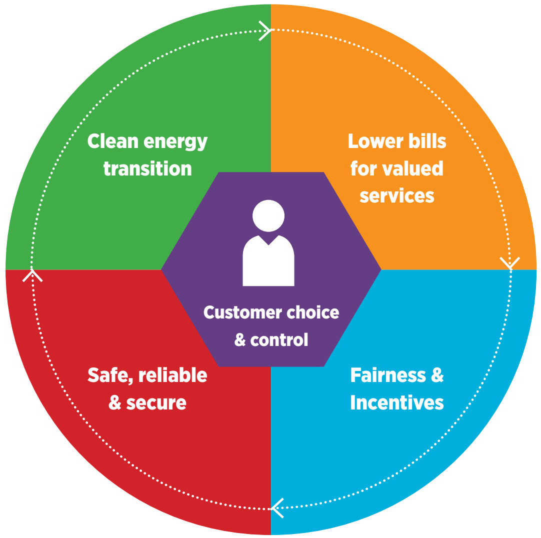
In such a dynamic context, Australia's energy future may unfold in many ways. No-one has perfect foresight on what may occur. *The Roadmap* program was initiated because some potential futures will produce demonstrably better customer outcomes than others.

Many aspects of long term transition simply cannot be planned and will depend on the forces of innovation, disruption and competition. In this uncertain environment, *the Roadmap* seeks to foster a context in which Australia's electricity networks give priority to anticipating and serving diverse customer needs.

Regardless of their level of engagement, the majority of Australians are expected to continue to value electricity solutions that are safe, reliable, affordable and sustainable. Increasingly, future network customers are also likely to have a voice in 'negotiated service' outcomes and in specific cases, may wish to trade-off some traditionally standardised service features such as universal reliability standards.

To provide a clear focus for developing *the Roadmap*, a Balanced Scorecard of Customer Outcomes (*Balanced Scorecard*) has been developed (Figure 1). It is recognised, however, that balancing these outcomes will require careful trade-offs involving a number of diverse stakeholders.

Figure 1: Balanced Scorecard of Customer Outcomes



Purpose and structure of this document

The purpose of this *Roadmap Report* is to provide stakeholders with an overview of key content developed through the detailed research and engagement phases of *the Roadmap* Program. The document commences by outlining the approach taken to program modelling and benefits evaluation. It then provides an overview of key elements that, together, function as an ecosystem of societal, technological, economic and regulatory sub-systems. The five areas of transformational focus are:

» **Customer oriented electricity:** Customers are placed at the centre of Australia's future electricity system and empowered with greater choice, control and autonomy while enjoying the security and benefits of a grid connection. Transformed electricity networks actively connect customers with a growing range of market actors and customised electricity solutions that are supported by a modernised customer safety net designed for the 21st century energy system.

» **Carbon abatement:** Incentive based policy options capable of enabling least cost carbon abatement are supported by options for maximising capacity utilisation. The transformed electricity system is positioned to efficiently maintain system reliability, support low emission energy technology growth and, achieve zero net carbon emissions by 2050.

» **Incentives and network regulation:** A fairer system through active implementation of network tariff and retail pricing reform and modernised regulation and competition frameworks. More customer oriented outcomes are supported ensuring that those without distributed energy resources are treated fairly while those with distributed energy resources are able to receive incentives for providing network support services that improve the efficiency of the grid for all.

» **Power system security:** Electricity networks and the power system as a whole are enabled to support an expanding diversity of energy sources, at both the customer and transmission levels of the system. System safety, security and reliability are a central focus and customer distributed energy resources are enabled to become an integral part of network optimisation and whole-of-system balancing.

» **Intelligent networks and markets:** An expanding range of new energy technologies and services are supported while continuing to efficiently provide a range of traditional electricity services. Advanced network planning, operation and intelligence systems ensure the safe and efficient integration of large scale variable renewable generation, hundreds of micro-grids and millions of customer distributed energy resources. Market based mechanisms reward customers with distributed energy resources for providing network support services, orchestrated either directly or by other market actors.

Each section includes a statement of a *2027 Resilient Future State*, an outline of research findings and a set of integrated milestones and actions to transition through the 2017-27 decade.

Electricity as a 'system of systems'

The Roadmap considers how the five areas of transformational focus as itemised above, might best operate together to deliver the optimal *Balanced Scorecard* outcomes. For example, the full development of a customer oriented network (Section 3) will require the development of advanced network valuation tools (Section 10) as well as a network optimisation market (NOM) where distributed energy resources services can be procured (Section 11). Similarly, the incentives that encourage effective distributed energy resources participation in this market requires a strategic focus on pricing and incentives (Section 7) that is supported by a range of regulatory considerations (Section 8).

Furthermore, in formulating the various milestones and related actions, *the Roadmap* recognises that no single player or industry sector can engineer the whole-of-system transformation necessary to deliver the overall benefits. While a deliberate effort has been made to identify actions that can be advanced by networks, a number of milestones and supporting actions would ultimately fall to other stakeholders and policy makers.

The 2017-27 decade is generally considered in two broad phases:

- **Foundation Phase (2017-22):** which outlines a process of grid modernisation and transition to improve data analytics and informational capabilities to lay a foundation for subsequent network transformation; and,
- **Implementation Phase (2023-27):** which outlines how a range of transformational activities deliver enhanced customer choice and value through enhanced network operations supported by advanced markets, advanced network planning and optimised renewables integration.

CSIRO and Energy Networks Australia recognise that a structured, evidence based roadmap, developed in consultation with a wide range of stakeholders, provides the best opportunity for Australia to effectively navigate the complexity of energy transformation. With an explicit and adaptable program of actions focused on customers' interests, Australia's electricity sector can exceed current abatement targets, keep the lights on and deliver lower costs to Australian households and enterprise.

Development of this *Roadmap* Report

The Roadmap program, undertaken over two years, has been informed by a wide range of stakeholder feedback and expert analysis. By setting out pathways to navigate the 2017-27 decade, Energy Networks Australia and CSIRO are seeking to place Australian customers at the centre of this critical transformation. No single entity or industry sector can successfully navigate this decade of change alone.

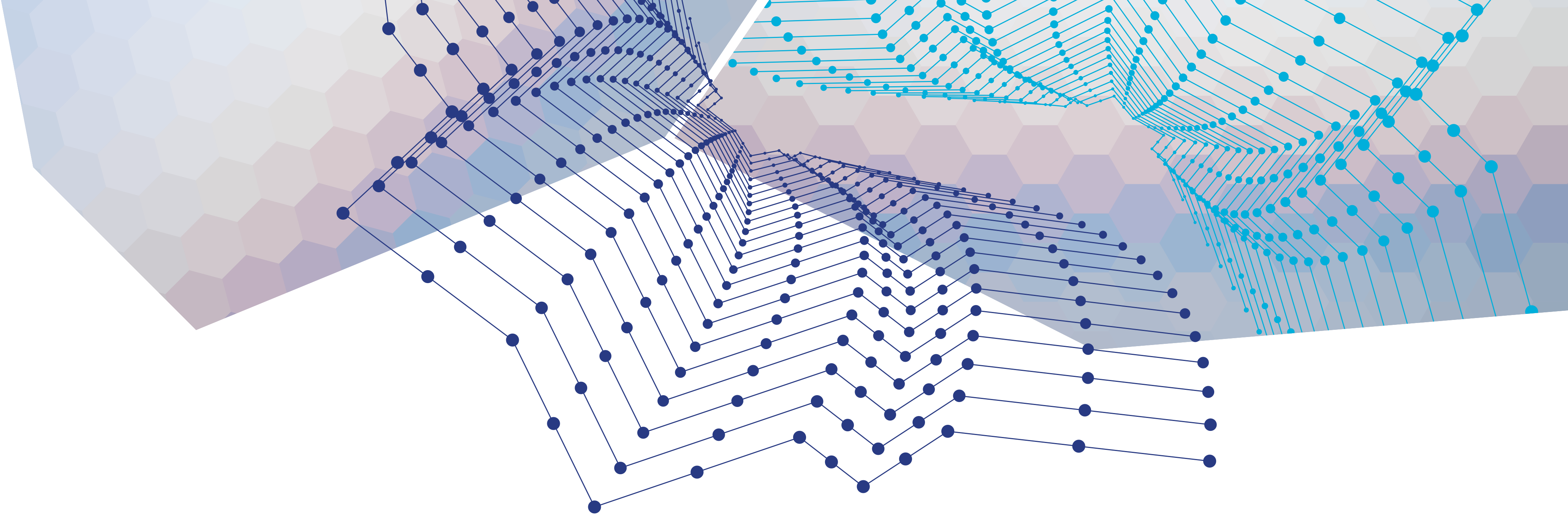
The Roadmap Program would like to thank the hundreds of stakeholders and experts who have contributed significant time and expertise over the last two years in the development of this consensus driven program of work.

This final Roadmap Report:

- Presents an integrated and sequenced set of actions across the five transformational areas, outlining time specific milestones to prioritise no regrets outcomes;
- Presents quantitative analysis of benefits from the proposed actions and transition pathways to 2027 and beyond; and,
- Provides strategies for addressing the barriers and constraints that inhibit addressing the priority actions.

Orientation of key report domains and sections

	FOUNDATION (2017, 2018, 2019, 2020, 2021, 2022)	IMPLEMENTATION (2023, 2024, 2025, 2026, 2027, 2027+)	KEY SECTIONS
CUSTOMER ORIENTED ELECTRICITY	Improve trust with customers	Networks provide responsive service platforms	[redacted] 3. Customer oriented networks 4. Customer safety net
POWER SYSTEM SECURITY	New systems to support diverse generation	Harmonised system operations at all levels	[redacted] 9. Power system security
CARBON ABATEMENT	A stable carbon policy for higher targets	Reviewing scope for greater efficiency	[redacted] 5. Carbon and renewable policy options 6. Efficient capacity utilisation
INCENTIVES & NETWORK REGULATION	Incentivising efficiency and innovation	Unlocking value of distributed energy resources with orchestration	[redacted] 7. Pricing and incentives 8. Regulatory and policy frameworks
INTELLIGENT NETWORKS & MARKETS	Essential information for an integrated grid	Active networks optimised with distributed energy resources	[redacted] 10. Grid transformation 11. Network optimisation platforms 12. Technical enablers - technical standards and regulations and future workforce requirements



PROGRAM EVALUATION AND BENEFITS

The Roadmap seeks to achieve the Balanced Scorecard of Objectives for Customers. Therefore, it is important to evaluate the effectiveness of the program and the value which is to be delivered. This is essential to justify the investment and focus required by all stakeholders to achieve these outcomes.

2. PROGRAM EVALUATION AND BENEFITS

Background

The Electricity Network Transformation Roadmap has been developed to actively engage with a significant period of change in the global electricity sector. It provides an evidence based action plan for realising the five customer benefits highlighted in the *Balanced Scorecard.*

Networks have a changing, but important, role in helping to enable balanced customer objectives through a connected energy future. Energy efficiency and deployment of millions of new distribution connected rooftop solar systems has been central to the evolution of the electricity system in the last six years, delivering greenhouse gas abatement and demand reduction (Figure 5). In parallel, the transmission system has been accommodating an increasing share of large scale wind and solar electricity generation to meet the 2020 Renewable Energy Target (RET).

The Roadmap can only be delivered through collaboration and action from all stakeholders. It is therefore important to evaluate whether *the Roadmap* will generate sufficient value to justify the investment and focus required by all stakeholders to deliver it. To this end, CSIRO has calculated the impact of the *Roadmap* and counterfactual scenarios to determine the value of the entire *Roadmap* (where quantification is possible). The counterfactual scenario describes what happens if *the Roadmap* is not implemented and the status quo or extension of current trends prevails.

The results in this section and in most cases throughout the report are presented at a national level. It is important to recognise that while *the Roadmap* actions are designed to be resilient to alternative futures, all projections are subject to uncertainty in their assumptions and outcomes. Furthermore, State level results are more diverse than the national picture and are provided in an appendix at the conclusion of this report.

Whole of Roadmap scenario

The Whole of Roadmap scenario includes combinations of activities from across the many Roadmap domains and milestones that support each other to deliver lower costs, decarbonisation, fairer prices and rewards for energy services and improved reliability. These have been simplified into three broad key elements for the evaluation of *the Roadmap* scenario as follows:

- **Price and incentive reform plus optimised networks and markets** means distributed energy resources adoption is enabled and delivering network capacity reduction tuned to each zone substation
- **Efficient capacity utilisation** is achieved through 20% adoption of electric vehicles by 2035 with managed charging
- **Electricity sector decarbonisation** does more than its proportional share of current national abatement targets (i.e. achieving 40% below 2005 levels by 2030) and accelerates that trajectory by 2050 to reach zero net emissions (100% abatement) due to strong power system security performance assisted by distributed energy resources orchestration

Counterfactual scenario

Conversely, the counterfactual scenario includes the following three broad key elements:

- Today's approach to pricing and incentive environment prevails (relying on customer opt-in to a retail tariff that is underpinned by a cost reflective network tariff) resulting in **slow and incomplete adoption of incentives for demand management**
- **No adoption of electric vehicles,** consistent with current national electricity system planning assumptions
- Electricity sector delivers abatement of 35% by 2030 and 65% by 2050 reflecting **ongoing carbon policy uncertainty and lack of confidence in and coordination of resources** for delivering lower emissions and high variable renewable energy (VRE) penetration with high power system security performance

Key findings

The findings for the benefits of delivering *the Roadmap* are summarised as follows.

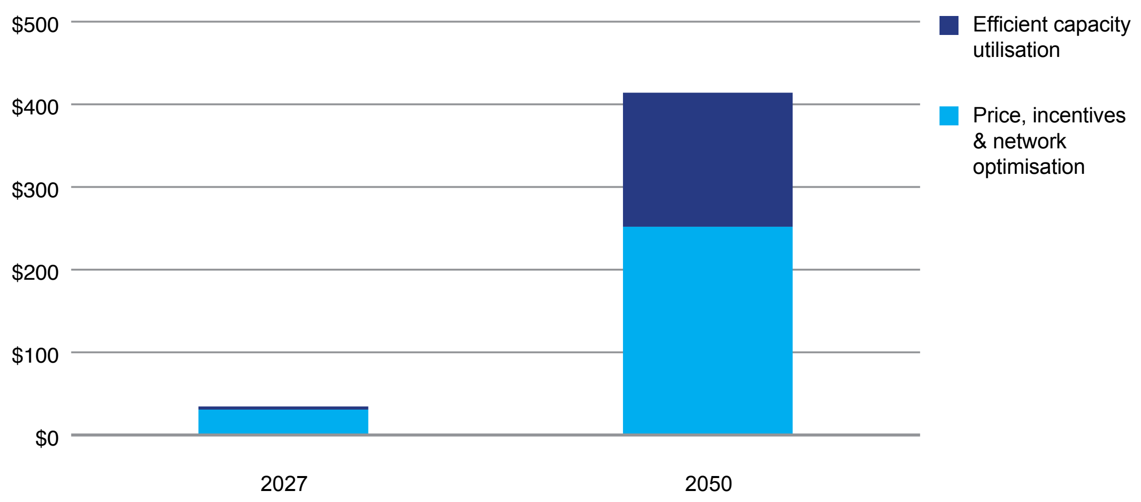
Residential electricity bills

The modelling logic for the delivery of lower residential electricity bills[1] under *the Roadmap* scenario is that there are two sources of savings. The first is that reformed prices, incentives and distributed energy resources network optimisation deliver a reduced need for expenditure on network capacity replacement or expansion. The second source of lower bills is a more efficient utilisation of capacity, because the cost of each unit of capacity is recovered from a larger customer base. Effectively, new uses of the energy network contribute to meeting system costs, with electric vehicle adoption (with managed charging), being the main driver of this outcome.

While electricity bills will increase due to higher costs associated with decarbonisation, Figure 2 shows that average residential electricity bills are lower under *the Roadmap* scenario in both 2027 and 2050 due to reduced network capacity expenditure and more efficient utilisation of the network. In 2050, the absolute reduction in average residential electricity bills relative to the counterfactual scenario is $414 per annum (in real terms).

A relatively modest average bill difference in 2027 does not reflect the potential for significantly different outcomes for some customer segments who are unable to take up distributed energy resources. For instance, a mid-size family which did not install distributed energy resources is approximately $350 per annum better off under *the Roadmap* scenario.

Figure 2: Projected savings in average residential bills (in real terms) under *the Roadmap* scenario



1 With around two thirds of customers expected to have distributed energy resources deployed at their premises by 2050, calculated electricity bills include the amortised costs of that equipment in addition to the cost of grid supplied energy.

Electricity system total expenditure

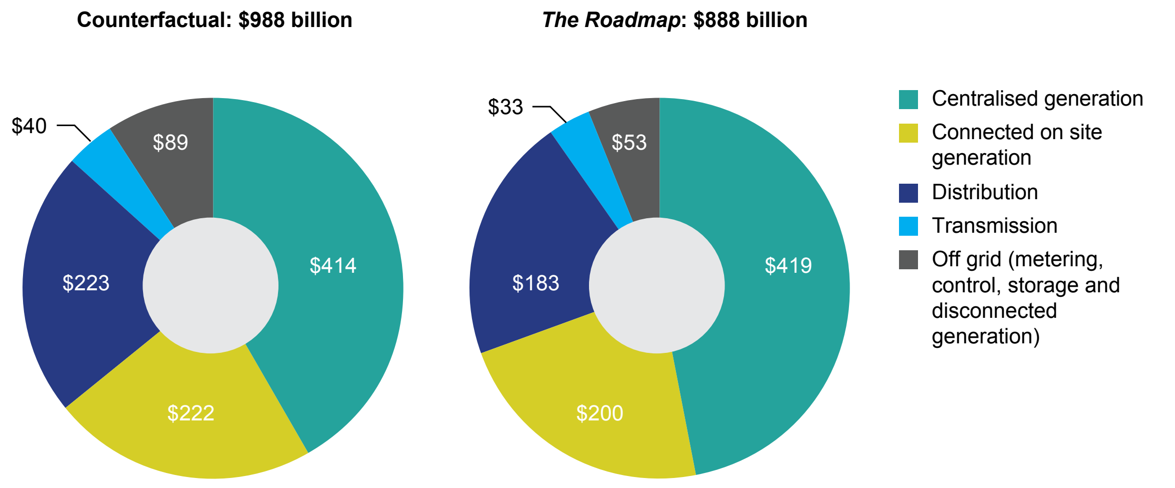
Price and incentives reform, together with the optimisation of distributed energy resources and network expenditures, reduces the need for expenditure on capacity. However, efficient capacity utilisation achieved through a larger customer base can mean increased fuel and operating costs. Total expenditure is therefore the appropriate unit for measuring changes in total system costs because it does not discriminate between capital and operations based solutions in any part of the electricity system.

The cumulative total expenditure for *the Roadmap* and Counterfactual scenario to 2050 are calculated for each major segment of the electricity supply and end-use chain (Figure 3). Overall, *the Roadmap* scenario achieves a real $101 billion reduction in cumulative total expenditure, primarily due to efficiencies in the distribution, off grid and connected on site generation sectors.

Greenhouse gas emissions

The Roadmap recognises the need for the network to play its role in delivering a more sustainable electricity system with reduced greenhouse gas emissions. As shown in Figure 4, by 2027, it is projected that distribution connected resources will deliver 37 MtCO_2e or 59 % of annual abatement (with variation between States). However, by 2050, the roles will have switched such that transmission connected resources will deliver 121MtCO_2e or 62% of abatement each year.

Figure 3: Cumulative electricity system total expenditure to 2050 (in real terms) under *the Roadmap* and counterfactual scenarios



The unexpected pricing and security events in South Australia in 2016 have increased the attention given to delivering low cost, secure, reliable electricity as Australia decarbonises. However, there is currently no enduring, clear long term climate policy. There is also a lack of integration between electricity sector planning processes and climate policy. These barriers to efficient decarbonisation will be exacerbated if distributed energy resources are not utilised to support system balancing, facilitated by network optimisation systems.

If these threshold issues are not addressed, CSIRO's analysis indicates the electricity sector will deliver less abatement than it is capable of and utilise a narrower and subsequently more sub-optimal set of resources to accommodate increased variable renewable penetration.

By contrast, if *the Roadmap* actions are delivered in regard to climate policy, power system security and network optimisation, *the Roadmap* scenario will deliver 69 $MtCO_2e$ more abatement, achieving zero emissions by 2050. This emission outcome is achieved at similar cost by 2050 compared to the counterfactual scenario (Figure 5). In the road transport sector, adoption of electric vehicles reduces emissions by 22 $MtCO_2e$ per year by 2050.

Figure 4: Historical and projected quantity of electricity sector abatement by location on the network (*Roadmap* Scenario)

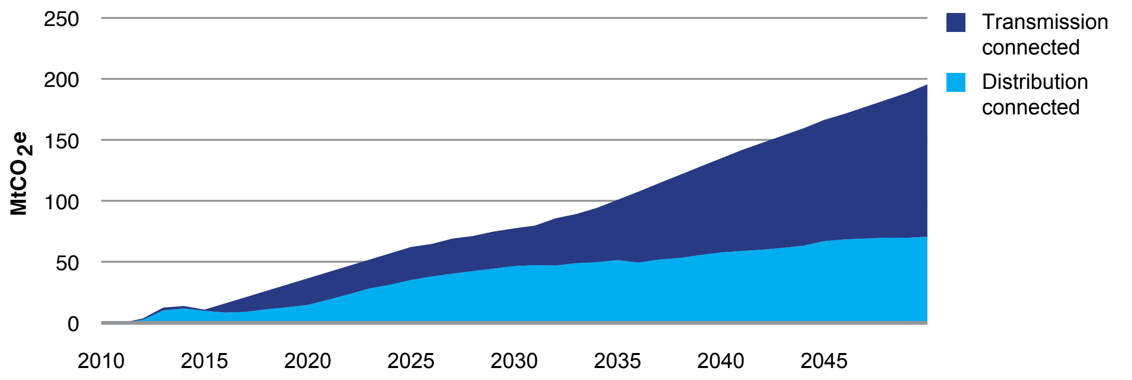
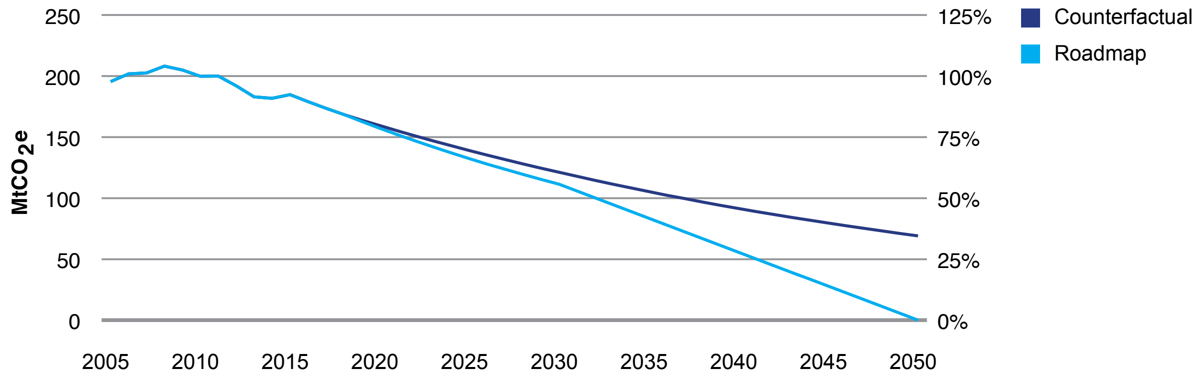


Figure 5: Assumed greenhouse gas pathways under *the Roadmap* and counterfactual scenarios (Left axis: emissions, right axis: % abatement relative to 2005 emissions)



Fairness and vulnerable customers

It is important to recognise that average customer outcomes can mask quite different outcomes for individual household types. While customer bills will differ due to different household energy needs, it is important to minimise inequitable outcomes or unintended cost transfers that might arise due to less cost reflective pricing structures, distorted incentives, or, customer vulnerability. Customer vulnerability is a term used to describe customers who are unable to take up opportunities that would enable them to save on electricity bills.

To examine these outcomes, CSIRO selected a set of sample customer profiles representing four household types. Electricity bills were calculated under two different assumptions. Firstly, it is assumed the customer was *active* in seeking distributed energy resources, including solar and batteries, to reduce energy bills (inclusive of the amortised cost of that equipment). Secondly it is assumed the customer was *passive* and did not, or could not, seek to invest in distributed energy resources to reduce energy bills.

Figure 6 shows that under the counterfactual scenario there is a significant difference between active and passive customer outcomes. Under *the Roadmap* scenario, which includes more cost-reflective pricing and incentives as well as other cost saving measures, there are two clear benefits. The first is that all customers are better off, whether they are active or passive. Secondly, the gap between active and passive customers has narrowed across the households by between 30 to 66 per cent.

Figure 6: Residential bill outcomes for selected Australian household types in 2050 under the counterfactual and *Roadmap* scenarios

	Counterfactual			*The Roadmap*		
	Active $	Passive $	The Gap $	Active $	Passive $	The Gap $
Working Couple	$1,346	$1,811	**$465**	$1,123	$1,422	**$299**
Medium Family	$1,816	$2,601	**$785**	$1,428	$1,988	**$560**
Large Family	$2,794	$3,950	**$1,156**	$2,346	$2,734	**$288**
Single, Retired	$1,058	$1,730	**$672**	$883	$1,355	**$472**

Business case evaluation and cost assumptions

The Roadmap has identified substantial multi-billion dollar savings in expenditure in networks and other parts of the electricity supply chain from delivering various key actions. Wherever possible, the investments required to enable quantifiable benefits have been incorporated in the analysis undertaken.

For instance, the investment in advanced metering required to support reforms to pricing and incentives as well as facilitate other benefits such as remote sensing and network operations are incorporated in the quantitative analysis.

Network optimisation systems which support distributed energy resources orchestration are not explicitly costed and would be assessed by the business case evaluation undertaken for individual programs, depending on the approach.

For instance, systems for rewarding distributed energy resources for providing services back to the grid already exist (e.g. off-peak hot water programs, PeakSmart air conditioning, battery storage trials). While there are a variety of delivery models, system investments in new platforms would be required to support the full scale and sophistication of more 10 million devices which could be integrated into the grid by 2050.

Further evaluation would be required by individual businesses considering the business case for such measures, with the normal regulatory review of expenditure where relevant. The success of existing programs and measures provides confidence that networks can deliver scaled up network optimisation systems for a fraction of the identified benefits of over $16 billion, with an emphasis on extending existing distributed energy resources orchestration approaches, where cost effective, in the immediate future.

Reference Documents

» Economic benefits of the Electricity Network Transformation Roadmap: Technical report, Brinsmead, Graham and Qiu (2017)

Overview of the Electricity Network Transformation Roadmap

FOUNDATION: 2017 | 2018 | 2019 | 2020 | 2021 | 2022

IMPLEMENTATION: 2023 | 2024 | 2025 | 2026 | 2027 | 2027+

CUSTOMER ORIENTED ELECTRICITY

Foundation: Improve trust with Customers
- Enhanced customer engagement and collaboration
- Customised choices, better information on services and new connection and advisory services
- Demonstrate investment reflects customer value while improving service performance and response times
- Review of customer protections and concessions

Implementation: Networks provide a service platform
- Open network platforms embrace diverse customer needs and aspirations
- Collaborate with customers and market actors to create new value with streamlined connections
- Leverage network information and digital services for personalised innovation in a dynamic market

POWER SYSTEM SECURITY

Foundation: New systems to support diverse generation
- Update Transmission Interconnection test
- Review frameworks for protection systems, efficient capacity and balancing services
- New market frameworks for ancillary services
- Develop new power system forecasting and planning approaches to anticipate system constraints
- Enhanced intelligence and decision making tools
- Close focus on physical & cyber security

Implementation: Harmonised system operations at all levels
- Transmission networks support system stability with new services.
- Distribution networks provide visibility of DER and potentially Frequency Control Ancillary Services (FCAS) and delegated balancing services.
- Real-time communication and controls

CARBON ABATEMENT

Foundation: A stable carbon policy for higher targets
- Develop nationally integrated carbon policy framework
- Implement emissions Baseline & Credit Scheme
- Set light vehicle emissions standard policy to provide incentives for electric vehicle uptake, supporting climate goals
- Review Australia's emissions reduction target
- Agile network connections and integration of large and small scale renewable technologies

Implementation: Reviewing scope for greater efficiency
- Review technology specific incentive schemes to focus on least cost abatement
- Review scope for more efficient economy wide carbon pricing where consensus
- Review Australia's emissions reduction target (2027)

INCENTIVES & NETWORK REGULATION

Foundation: Incentivising efficiency and innovation
- Ensure extensive smart meter penetration
- Assign customers to new range of fairer cost reflective network tariffs, with a choice to opt out
- Enable standalone systems and micro-grids as a substitute for traditional delivery models
- New innovation incentives in regulation and competition frameworks

Implementation: Unlocking value of distributed energy resource orchestration
- Networks pay for distributed energy resource orchestration to provide system support in the 'right place at right time'
- New network tariffs that provide beneficial incentives for standalone systems and micro-grids to stay connected to the grid
- New and more adaptive regulatory approaches that are customer focused

INTELLIGENT NETWORKS & MARKETS

Foundation: Essential information for an integrated grid
- Establish open standards and protocols to enable secure system operation, management and exchange of information and interoperability with distributed energy resources
- Networks enhance current system monitoring and models to inform advanced system planning
- Build distributed energy resource maps and feeder hosting analysis to support locational valuation of distributed energy based services

Implementation: Networks optimised with distributed energy resources
- Active network management for technical stability, enabling distributed energy resource markets and efficient optimisation
- Networks provide a suite of grid intelligence and control architectures to animate distributed energy resource markets, as well as providing system security
- Establish a new network optimisation market to procure DER services for network support
- A flexible and agile workforce to support the new optimised energy system

Overall Customer outcomes by

	2027	2050
CUSTOMER CHOICE AND CONTROL	» Over 40% customers use onsite resources: 29 GW solar and 34 GWh of batteries. » Concessions to support those who need it most.	» Almost 2/3 customers use onsite resources, including 1/3 customers on a new stand alone system tariff.
LOWER BILLS FOR VALUED SERVICES	» Avoid over $1.4 BN in network investment. » Average network bills 10% lower than 2016.	» Total system spend is $101BN lower to 2050. » Save households $414 pa by 2050. » Network charges 30% lower than 2016.
FAIRNESS & INCENTIVES	» Networks pay over $1.1 BN pa for DER services. » Over $1.4 BN in cross subsidies avoided, saving $350 pa for med size family without DER.	» Networks pay over $2.5 BN pa for DER services. » Over $18 BN in cross subsidies avoided, saving $600 pa for med size family without DER.
SAFETY, SECURITY, RELIABILITY	» Planned and efficient market response avoids security & stability risks. » Robust physical & cyber security management.	» Real time balancing, reliability and quality of supply at small and large scale, with millions of market participants.
CLEAN ENERGY TRANSITION	» Electricity sector carbon abatement to reach 40% by 2030 – greater than current national target of 26-28%.	» Electricity sector achieves zero net emissions by 2050.

CUSTOMER ORIENTED ELECTRICITY

Customers are placed at the centre of Australia’s future electricity system. They are empowered with greater choice, control and autonomy while enjoying the security and benefits of a grid connection. Transformed electricity networks actively connect customers with a growing range of market actors and customised electricity solutions that are supported by a modernised customer safety net designed for the 21st century energy system.

3. CUSTOMER ORIENTED NETWORKS

Background

For many customers, the 2017-27 decade will see dynamic changes in the way they consume, produce and value electricity and related network services.

Customers are being provided with unprecedented choice and control over how and when they consume electricity. This is driven partly by the uniquely high penetration of distributed energy resources in Australia, including mass adoption of solar photovoltaic (PV) panels, the increasing affordability of energy storage and the growing trend towards growing digitisation and customisation of services.

The shift in customer value and decision making power is particularly striking for customers at the edge of the grid. These trends present a range of opportunities for creating new services and better ways of supporting customer expectations.

This chapter identifies the need for electricity networks to understand shifting customer value drivers and transform their businesses to deliver clear value to customers. Networks should provide a trusted service platform enabling customers to access the expanding market of electricity services and products by:

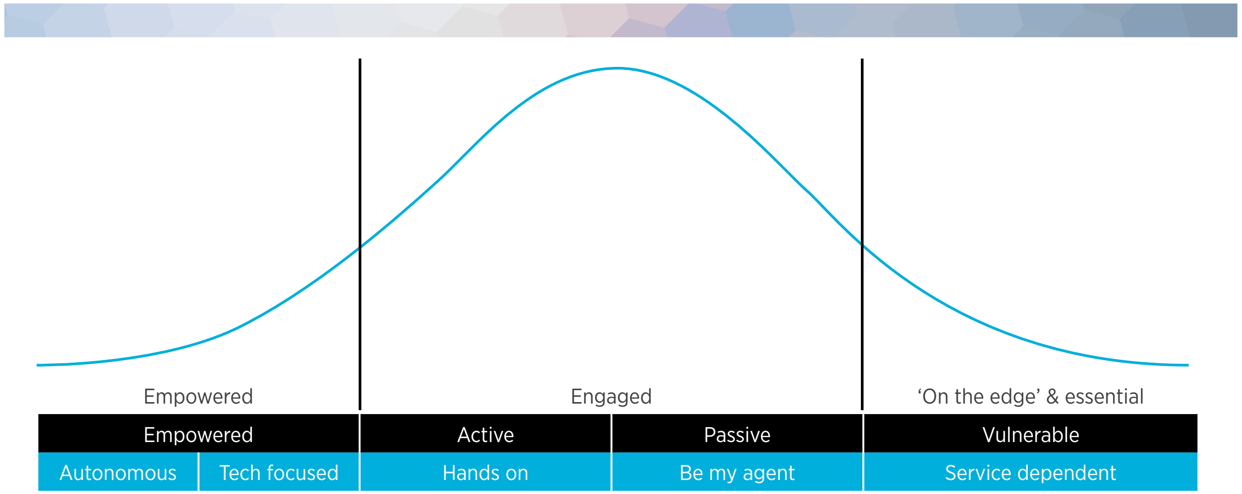
- Providing customers with a strong, informed voice in shaping future network operations and services, underpinned by improved information sharing and access to network data
- Anticipating and supporting emerging customer needs by facilitating tailored products and services which offer customers greater choice
- Transforming the network business model to align future network products and services with the needs of customers and the diverse market actors which will create value on the grid platform

Drivers of change

A shift towards enhanced customer choice, control and empowerment is being driven by:

- Increasingly diverse customer energy use and engagement, not well correlated with traditional factors like socio-economic groups or specific business types
- Customers directly investing to reduce consumption, generate, store and control electricity usage via on site distributed energy resources for cost, independence, reliability and environmental goals
- New edge-of-grid capabilities enabling multi-directional flows of power and information, so end users can sell services to networks and other market actors
- The end of the traditional supply chain, replaced by multiple commercial relationships in new energy service markets
- The growth of digital channels and platforms making it easier to choose, connect and swap between energy products and services

Figure 7: Example of market segmentation curve for residential customers in 2027 (See *the Roadmap Interim Program Report* Dec, 2015).



Source: Plausible 2027 customer segments were informed by an international literature review, commissioned expert papers and structured stakeholder workshops. In particular, Rosemary Sinclair of Energy Consumers Australia is acknowledged for employing the market curve device to graphically represent customer segments (adapted with permission).

- Customer expectations of a responsive grid, enabling streamlined connections and a 'plug and play' environment supporting their choice of technologies

Resilient 2027 Future State

- By 2027 electricity solutions are highly customised to diverse household, business and community needs with appropriate protections
- End use customers empowered to adopt a growing range of innovative energy solutions that provide greater autonomy with the security of grid connection (where required)
- Networks enable new customer value with and on behalf of diverse market actors and customer agents through financially valuing system benefits provided by distributed energy resources
- Customer and market actor trust enhanced through deep engagement and a track record of value creation, customer empowerment and market animation

Key findings

Electricity networks are being transformed through growing customer investment in distributed energy resources and energy saving technologies. Consequently, they need to become more customer oriented. Networks will need to keep their focus on end users and other customers during this dynamic time, to demonstrate the ongoing value of the grid in supporting and delivering improved customer choice, value and personaliSation of electricity products and services.

The following themes will require priority as networks pursue a focus on customer orientation:

Finding 1: Networks need to enhance relationships with customers built on improved data analytics capabilities and a deeper understanding of increasingly diverse customer needs.

Networks will be expected to demonstrate the voice of customers has been heard and prioritised in determining network services and investments.

Improved data analytics capabilities will also allow networks to deepen their understanding of end customers and assist in the customisation and tailoring of information and services to changing customer needs.

Finding 2: Networks should seek to expand information services to enhance interactions with customers.

New channels of customer assistance are likely to be required, including advisory and information services shaped by increasing personalisation.

Networks must develop information services so customers can access more transparent data in relation to the adoption and connection of a growing range of products and services. The increasing use of digital channels will also provide simple and seamless means through which customers can interact with networks and access greater levels of information. This will also underpin improved customer service outcomes, such as response times and outage management.

Finding 3: Networks will play a key role in the delivery and connection of an expanding range of innovative products and services to customers.

New products and services will be needed to reflect changing technologies and opportunities for customer benefits, including network support services for micro-grids, standalone power systems, peer to peer trading and electric vehicles.

Networks may forge new collaborations and partnerships with non-network market actors to empower all customer types with access to the energy solutions they value most.

Reference Documents

Roadmap program documents that provide additional background to these findings include:

- Electricity Network Transformation Roadmap: Interim Program Report (2015)
- Electricity Network Transformation Roadmap: Customer Engagement Handbook (2016)
- Network business model evolution: an investigation of the impact of current trends on DNSP business model evolution, Accenture (2015)
- Insights from global jurisdictions, new market actors & evolving business models, Accenture (2016)

2017-27 Milestones

The Roadmap outlines a series of milestones which provide markers of progress over the decade toward the *Resilient 2027 Future State*. Each of the milestones are supported by a series of integrated actions.

Milestone 1: By 2018, network customer engagement and collaboration has regular, credible processes, underpinned by greater access to shared information, which begin to enhance trust.

Electricity networks build effective customer engagement to strengthen the voice of the customer in decision making and to align better outcomes for end users and other customers. Effective engagement is supported by a culture across the organisation focused on delivering effective customer outcomes and seeking customer guidance and input frequently.

Networks pursue continuous improvement for meaningful and successful engagement including best practice principles of transparency, responsiveness, inclusiveness, materiality and measurement.

Milestone 2: By 2021, electricity networks are recognised for demonstrating that their investments are based on customer value, improving service performance and response times, and enabling more flexible network products.

Significant change management and efficiency programs are being implemented across electricity networks. The five-year investment programs of network service providers reflect customer's feedback on their value and priorities.

Network service outcomes are achieved with innovative alternative delivery methods that reflect the value of deferring significant capital expenditure. Smart grid investments and the take up of digital technologies within network businesses ensure two-way energy flows are balanced without incurring additional network investment and enable faster response times and faster, more transparent, outage management.

As highlighted in *Section 7 – Pricing and incentives*, networks introduce new products and services like a standalone power system tariff, micro-grid support services or incentives to large customers for new transmission connections in strategic locations. Networks actively seek to utilise customer owned distributed energy resources, where cost effective, to avoid network investment when localised import or export constraints arise.

Milestone 3: By 2024, electricity customers and market actors trust networks as active enablers of expanding products and services with streamlined connections which avoid impacts on other customers.

Electricity networks intensify their focus on the new technologies and services customers and market actors expect from the grid. Connection processes for customer technologies are streamlined and made more nationally consistent, supporting new market entrants and innovative services. Networks contribute to whole of industry standards and communication protocols which enable customers to realise greatest utility and financial returns from their choices.

"Orchestration" allows the free flow of energy, including the reverse flow of energy between localised low voltage network areas and into higher voltage networks. Networks have the visibility and the market tools to economically balance energy flows without the need to "build out" constraints.

Networks support customer decision making with improved advisory and information services. Operational communications are increasingly customised with potential feedback on customer resources.

Milestone 4: By 2027, network information and digital services provide a platform for stimulating customised energy options in dynamic markets.

Enhanced data analytics capabilities and increasing use of digital channels enable improved two-way information flow between customers and networks. These capabilities also underpin enhanced sharing of data with a range of service providers, aggregators and retailers to ensure streamlined connection of products and services. Networks also build relationships and evaluate opportunities to support delivery of energy product and services with third parties, particularly in network areas where opportunities may emerge to procure network services from customers and third parties.

From 2020, mature digital services and communication platforms are developed and gradually improved to enable streamlined, simple, straightforward and customised interactions with a diverse range of customers.

Key benefits

Improved data analytics and segmentation underpins enhanced engagement which drives deepening relationships with an increasingly diverse range of customers, customer representatives and energy service providers and retailers.

A deeper understanding of diverse customer needs allows networks to facilitate the delivery of a growing and targeted range of products and services in collaboration with a diverse range of market actors. These partnerships and improved data capabilities allow networks to shape services to serve local network needs in return for enhanced customer outcomes.

Improved information services and access to data

Improved data analytics and digitalisation of services will provide customers with improved access to data, information and connection services. This will improve customer outcomes in terms of more seamless choice and connection of new products and services. It will also provide better information and education in an increasingly complex system.

Improved data capabilities will enable networks to deepen customer relationships and assist in providing more up to date information, tailored to customer needs when customers require it.

Enhanced distributed energy resources integration

By 2027, over 40% of customers will have adopted on site distributed energy resources supported by simple and supportive network information services. Network analytics and data support the efficient integration of distributed energy resources across the network, with one in three customers incentivised to allow their distributed energy resources to support local network needs thereby improving network efficiencies and operations for all customers.

Enhanced choice and control

Networks support the adoption and connection of a growing range of electricity services and products by providing improved access to data and information services.

Retailers offer customers a broader range of options as to how they use and pay for energy services. Engaged customers will be offered more cost reflective signals to respond to wholesale markets and grid service market signals. Other customers will take up simpler bundled price offerings, allowing retailers or other market actors to manage volatility in upstream markets.

Improved analytics and use of digital channels and services allows customers to choose and connect a range of energy services and products in a seamless and straightforward manner, supported by close relationships with a range of energy service providers, aggregators and retailers.

Networks are well placed to provide a range of valuable services to customers including enhanced information and decision support tools.

Networks as Service Platforms

As networks become more customer focused and enhance the services and information that they provide and share with customers, they will progressively become platforms that connect customers with growing ranges of energy products and services while also enabling customers to trade in increasingly dynamic markets.

To enable this, networks will need to progressively implement new capabilities to support growing customer choice. This will involve; 1) enhancing grid analytics with smart grid technologies and devices to optimise grid operations and informational services; 2) improving the integration of distributed energy resources into network operations; and 3) developing grid capability to establish a platform to accommodate, integrate and serve the full range of distributed energy resources and growing range of energy service providers.

Importantly network service platforms will allow the growing range of energy services providers, aggregators and other customer facing platform providers to have open access to customers and markets.

2017-27 Milestones and actions[2]

FOUNDATION						IMPLEMENTATION					
2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2027+

CUSTOMER ORIENTED ELECTRICITY

Improve trust with customers through better engagement, customised services and reform of customer protection frameworks

Networks provide a service platform that is responsive to the changing needs of diverse customers and which provides open information stimulating new market innovation

COMMUNICATION & ENGAGEMENT

Milestone 1

By 2018, **network customer engagement and collaboration** has regular, credible processes, underpinned by greater access to shared information, which begin to enhance trust

- Implement biennial engagement forums to share engagement practice learnings
- Implement industry wide tracking and evaluation of engagement practices
- Implement and leverage digital capabilities providing content rich and accessible services and information
- Leverage customer analytics to drive cost efficiencies and improve network services
- Segment customers in terms of what they value to personalise communications and information

CUSTOMISED ENERGY SOLUTIONS

Milestone 2

By 2021, electricity networks are recognised as demonstrating their **investments are based on customer value; improving service performance** and response times; and enabling more flexible network products

- Enhanced processes, data analytics, digital customer interface enable streamlined connection of growing range of DER
- Build capability to share network data clearly with market
- Evaluate opportunities to support delivery of DER services with 3rd parties

Milestone 3

By 2024, electricity networks are trusted **by customers and market actors as active enablers of expanding products and services** with streamlined connections which avoid impacts on other customers

- Trial and prototype localised products, services and information services with 3rd party partners
- Scale proven services
- Establish open access, bundled customer programs supporting local grid needs

Milestone 4

By 2027, network information and digital services **provide a platform for stimulating customised energy options** in dynamic markets

- Build on digital informational customer channels, develop increasingly digitalized platform capable of managing customer enquiries, connections and installations
- Digital platform established for simple streamlined customer interactions, engagement and interconnection
- Customer facing network digital platforms integrated with emerging Network Optimisation Market (Section 11)

2 Milestone timings are developed as a national guide for Roadmap Implementation. Timing of milestones and actions will differ across jurisdictions and different network areas. Milestone timings are specified as a latest end date, but many will require early action and may be completed earlier than outlined

4. CUSTOMER SAFETY NET

Background

Customer protection will be a critical underpinning of the dynamically changing, customer centric energy system. There is a strong need to avoid fragmentary energy market regulation which fails to protect customers in a period of disruption.

Inflexible and non-responsive regulatory frameworks that do not recognise emergent competition and which unintentionally constrain customer choice, competition and efficient outcomes have the potential to harm the long-term interests of energy customers.

Drivers of change

- The potential for the regulatory framework to stifle delivery of customer valued services in a variety of competing business models, operating on a level playing field to deliver value
- The potential for an inadequate consumer protection framework to stifle delivery of customer valued services by a failure of confidence to participate in new service and product choices
- Emergence of the potential for off grid and competition in network services to lead to an unplanned and disruptive break down of the funding of the commons of a shared network service capable of integrating efficient levels of centralised generation and distributed energy resources that meet customer needs

Resilient 2027 Future State

- By 2027, customer interests are protected by strong and effective customer safety net arrangements which underpin confident participation in new service markets, while protecting vulnerable customers from hardship in a targeted way
- Customers are empowered to make their personal energy choices with clear information

Key findings

Finding 1: Robust framework needed

Providing a robust customer protection framework enabling customers to make confident choices in new markets, and between new service/product bundles. This is important because the dynamic changes occurring in energy technology, capabilities, markets and business models are increasingly presenting customers with a wider set of energy choices. Enabling and sustaining these markets requires a customer protection framework that enables customers to choose services that fit their needs with confidence and keep their customer rights are safeguarded.[3]

Finding 2: Clear rules for market entry and participation

A clear set of road rules addressing the market entry and participation decisions from providers. This is required to minimise regulatory arbitrage that has the potential to harm customers' interests. The ability for customers to access innovative new services and be well served by new businesses trialling and evolving new business models, is underpinned by clear rules that ensure that customers are benefiting from genuine innovation, not artificial innovation based only on market participants exploiting regulatory loopholes, or failing to contribute to agreed customer safety nets.[4]

Reference documents

Documents that provide additional background to these findings include:

- Power Transformed, Consumer Action Law Centre (July 2016)

3 Power Transformed, Consumer Action Law Centre July 2016, p.4
4 Power Transformed, Consumer Action Law Centre July 2016, p.38

2017-27 Milestones

The Roadmap outlines a series of milestones which provide markers of progress over the decade toward the *Resilient 2027 Future State*. Each of the milestones are supported by a series of integrated actions.

Milestone 1: Universal new energy services framework

By 2018, develop and implement a universal authorisations and exemptions framework for the provision of new energy services where currently inadequately addressed by national electricity and/or consumer law.

Milestone 2: Transparent information for customers making choices

By 2018, develop and implement a code of practice to ensure consumers receive appropriate information before they enter into a contract for the provision of energy and/or new energy services.

Milestone 3: Resolving reconnection rights and responsibilities

By 2019, examine and set down the rights and responsibilities of small consumers regarding the provision of electricity, including grid reconnection, where sought.

Milestone 4: Addressing national hardship and concessions

By 2020, examine and set down the minimum consumer financial hardship requirements applicable across all energy and new energy services providers. By 2022, establish a nationally consistent framework for energy concessions and emergency assistance that ensures the most vulnerable consumers can afford to remain connected to electricity supplies.

Key benefits

Revised national approaches to customer protection

Introducing a universal national energy services framework and improving information for customer choices on new technologies and services would make a material contribution to supporting active, confident participation in new energy service markets. This in turn fosters innovation and competition to serve the interests of customers with more tailored services and products.

Similarly, clarifying future rights and responsibilities related to reconnection is important to avoid unforeseen consequences in cost allocation or inequity emerging between customers. Supporting a predictable regulatory framework allows for the optimisation of customer and grid investments.

The review of national hardship and concession arrangements provides important benefits to vulnerable customers in need of support and increases the long-term sustainability of support measures.

2017-27 Milestones and actions[5]

FOUNDATION						IMPLEMENTATION					
2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2027+

CUSTOMER ORIENTED ELECTRICITY

Improve trust with customers through better engagement, customised services and reform of customer protection frameworks

Networks provide a service platform that is responsive to the changing needs of diverse customers and which provides open information stimulating new market innovation

CUSTOMER SAFETY NET

Milestone 1
By 2018, develop and implement a **universal authorisations and exemptions framework for the provision of new energy services** where inadequately addressed by National Electricity and/or Consumer Law

- Consider scope of framework
- Develop framework

Milestone 2
By 2018, develop and implement a **code of practice to ensure consumers receive appropriate information** before they enter into a contract for the provision of energy and/or new energy services

- Form working group to develop code of practice
- Finalise code of practice

Milestone 3
By 2019, examine and set down the **rights and responsibilities of small consumers regarding the provision of electricity**, including grid re-connection where sought

- Review rights and responsibilities in light of market and technology changes
- Develop agreed set of rights and responsibilities in light of market and technology changes

Milestone 4
By 2020, set down minimum consumer financial hardship requirements. By 2022, establish a **nationally consistent framework for energy concessions and emergency assistance** for those who most need it

- Review minimum consumer financial hardship requirements in light of market and technology changes
- Develop agreed set of minimum consumer financial hardship requirements in light of market and technology changes

5 Milestone timings are developed as a national guide for Roadmap Implementation. Timing of milestones and actions will differ across jurisdictions and different network areas. Milestone timings are specified as a latest end date, but many will require early action and may be completed earlier than outlined

CARBON ABATEMENT

Incentive based policy options capable of enabling least cost carbon abatement are supported by options for maximising capacity utilisation. The transformed electricity system is positioned to efficiently maintain system reliability, support renewable energy growth and achieve zero net carbon emissions by 2050.

5. CARBON AND RENEWABLE POLICY OPTIONS

Background

Australia has committed to a 26 to 28% abatement target over 2005 level by 2030. The agreement reached in Paris in December 2015 consists of two broad international targets. Firstly, to reach peak emissions as soon as possible and secondly, to reach carbon neutrality in the second half of this century. Australia is currently on track to reach its 2020 emissions target but will require additional or strengthened policy settings to reach the 2030 target and/or to become carbon neutral in the second half of the century.

Drivers of change

The key drivers of change impacting Australia's carbon abatement include:

» International agreements on greenhouse gas reduction, both in the medium term to 2030 and the longer term to 2050

» Government policy settings to achieve these agreements

» Direct policy measures to support specific technologies including renewables and clean energy, including at specific (large or small) scales

» Improvements in capital costs and efficiency of renewable energy generation and energy storage

Resilient 2027 Future State

» By 2027, Australia is on track to achieve or exceed the 26 to 28% carbon abatement target by 2030, in line with the agreed Australian international emissions reduction target[6].

» Australia's electricity sector is positioned to support further carbon abatement targets beyond 2030 and is on track to achieve zero net carbon emissions by 2050

» The structured transition has minimised the cost of abatement to customers and the economy, enabled the integration of diverse low carbon energy sources and protected energy security, reliability and quality of supply

Key findings

Jacobs was commissioned to model policy options to meet Australia's 2030 abatement target from the stationary energy sector. The options considered were:

» **Business as usual** – where the suite of current government policies continues and major policy settings (i.e. the reduction of absolute baselines) are adjusted to reach specific abatement targets

» **Technology neutral** – where the current suite of policies is adjusted to become technology neutral and elements of a baseline and credit scheme are introduced

» **Carbon price mechanism** – where all policies are removed and replaced by a carbon price on all emissions

Two targets were considered;

1. 26 to 28% below 2005 levels by 2030, and
2. 45% below 2005 levels by 2030.

For the purposes of *the Roadmap*, the focus will be on the findings of the 26 to 28% target.

The analysis undertaken by Jacobs shows that the Government's abatement target for 2030 can be met by any of the three policy scenarios. The main difference between the scenarios is the change in fuel mix and the impact this has on the total economic cost during the next decade, as well as on household bills.

Finding 1: Emission reductions of 26 to 28% from the stationary energy sector can be achieved with any of the selected policy scenarios

The modelling indicates that emission reductions of 26 to 28% from the stationary energy sector can be achieved with any of the selected policy scenarios. The 2030 emission level for electricity of 127 Mt CO_2 and the cumulative emissions over the decade are achieved in all scenarios indicating that they all achieve the same abatement outcome. The electricity sector does more than its share with its reductions being reduced by 36% over the 2005 baseline level. The main difference between scenarios is in the cost to achieve the abatement.

6 COP 21, Paris Agreement, Intended Nationally Determined Contribution

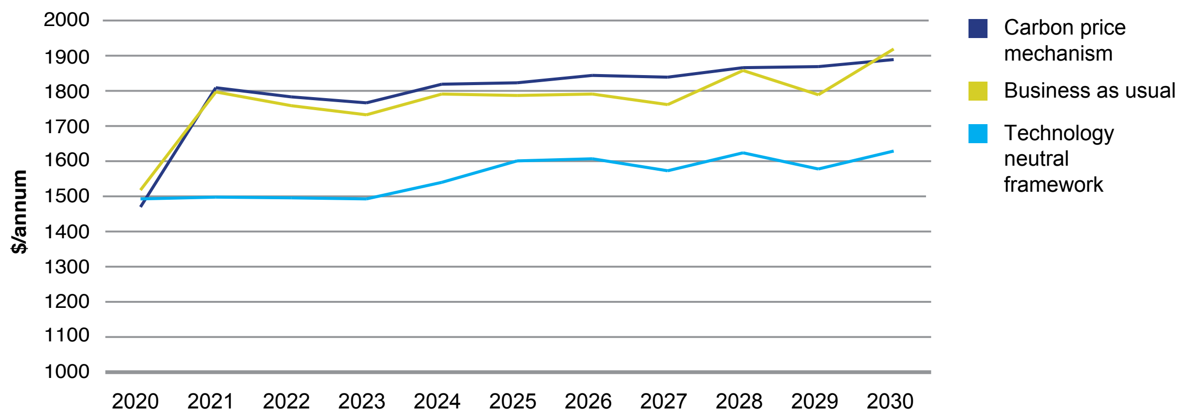
Finding 2: Household bills are lower under an emission intensity baseline and credit scheme.

Household bills are affected by changes to the wholesale electricity or gas price and/or by the additional impost from trading, where it can occur. The lowest household bills occur in the 'technology neutral' scenario. This reflects a lower wholesale price compared to the 'business as usual' scenario since the reduction in absolute baselines is modified to become an emission intensity baseline and credit scheme. In this instance trading can occur within the generation sector to achieve an average emission intensity across the sector.

The 'technology neutral' scenario saves an average of $216 per year on electricity bills compared to 'business as usual'. It does not impact on gas bills as there are no changes to wholesale gas prices between the scenarios.

The carbon price mechanism applies a carbon price to all carbon emissions and increases all household bills. In this scenario, bills are higher for both electricity and gas (Figure 8). However, it should be noted that there are opportunities for governments to develop appropriate financial transfers to provide household support and offset these higher bills.

Figure 8: Impact of policy settings on household electricity bills



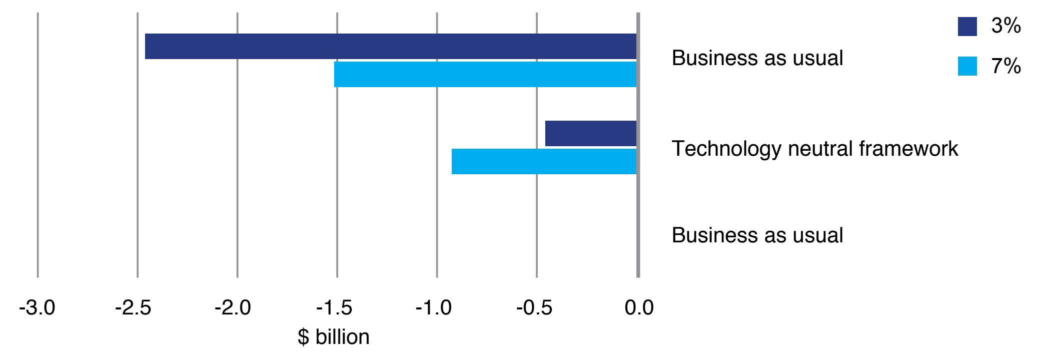
Finding 3: Policy settings impact the economic cost of emissions reductions

The economic cost reflects the capital cost for new plant and interconnectors, retirement costs of plant being removed from the system and operating and fuel costs to meet energy demand. It is estimated as the net present value in 2020 for all the costs for the decade from 2020 to 2030. The resource cost for the business as usual scenario is $129 billion. A lower resource cost is required in the other scenarios as they allow a more efficient use of existing infrastructure. The savings over the decade in these other scenarios range between $0.9 to $1.5 billion (Figure 9).

Finding 4: Gas and non-hydro renewable power generation increases to achieve the abatement target

The fuel mix changes substantially for power generation between 2020 and 2030 to achieve the abatement target. The fuel mix in all scenarios changes from being coal dominant to becoming more diverse with renewables, gas and coal all contributing more equally in 2030. The generation from renewables is roughly constant across the three scenarios, growing from the 2020 Large Scale Renewable Energy Target (LRET) level and reaching levels of between 74,500 GWh and 80,000 GWh in 2030, representing approximately 30% of the energy mix. Small amounts of renewable energy generation are added between 2020 and 2025. Additional renewable generation occurs beyond 2025 and does not need new support in the form of an expanded Renewable Energy Target (RET) to drive additional take up.

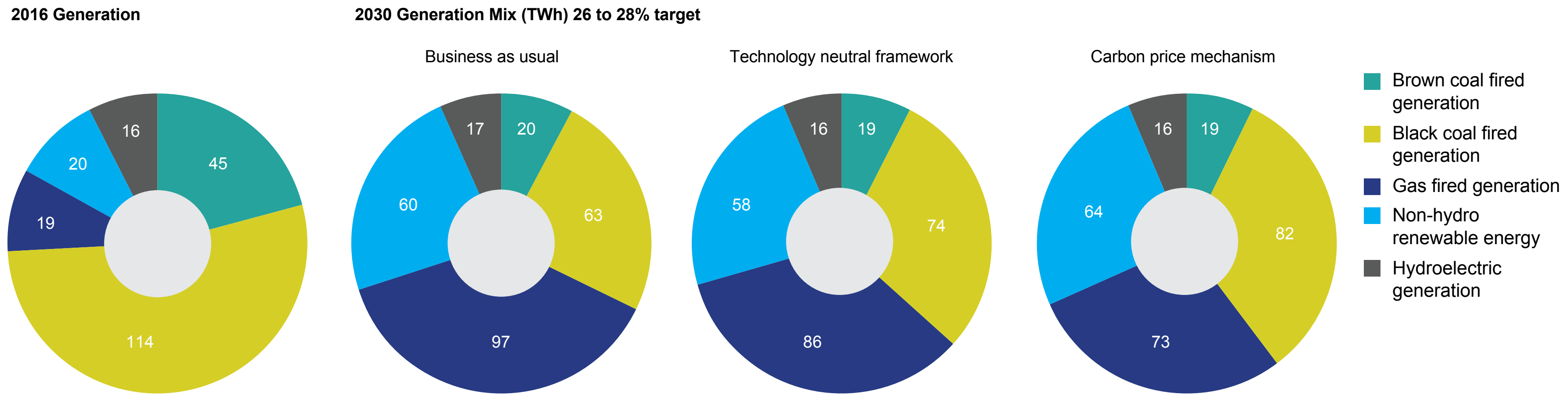
Figure 9: Impact of policy settings on total economic cost



Finding 5: Technology neutral carbon policy will support higher Australian international commitments

Technology neutral carbon policy will support higher Australian international commitments. The Australian Government has committed to a 26 to 28% target by 2030. As part of the global agreement reached in Paris, governments around the world have agreed to strengthen their nationally determined contributions, with the aim of avoiding global warming by 2.0°C. This will require countries to become carbon neutral in the second half of this century. The Australian Government has undertaken to complete a review of its climate policy settings and its 2030 abatement target in mid-2017.

Figure 10: Growth in renewable generation under all policy scenarios



The analysis by Jacobs also considered a more ambitious abatement target of 45% reduction by 2030. The modelling indicated that this target could be achieved, although it required a higher overall economic cost (between $17.9 and $26.3 billion extra) and higher household bills compared to the 26 to 28% target. Nevertheless, the relative benefits between the scenarios was the same as for the 26 to 28% target.

This analysis indicates that the least impact on customers is to adopt a Technology neutral scenario in the near term, but that the lowest total economic costs requires a carbon price mechanism. Clearly this mechanism would need to consider how revenue raised would be returned to households to address net financial impacts.

Reference documents

Documents that provide additional background to these findings include:

- Enabling Australia's clean energy transition, Energy Networks Australia (2016)
- Australia's climate policy options - modelling of climate policy scenarios for Energy Networks Australia, Jacobs (2016)

2017-27 Milestones

The Roadmap outlines a series of milestones which provide markers of progress over the decade toward the *Resilient 2027 Future State*. Each of the milestones are supported by a series of integrated actions.

Milestone 1: By 2017, agree an enduring, stable and nationally integrated carbon policy framework avoiding the extension of further technology specific incentives.

A core design requirement of future carbon policy frameworks should be their durability and stability based on stakeholder consensus. Australian governments should prefer:

- Policy options that have a reasonable prospect of bipartisan and intergovernmental consensus to provide a stable investment environment that secures both carbon abatement objectives and efficient investment
- Policy options that secure tangible progress towards efficient carbon abatement and avoid polarisation or retrospectivity

Milestone 2: By 2020, commence an emission intensity baseline and credit scheme or alternative policy of similar merit to achieve the nationally agreed 26-28% emission reductions by 2030 from the electricity sector.

The target can be achieved through a baseline and credit scheme within the electricity sector.

- Through tightening of the average intensity baseline, electricity generation emissions could be progressively reduced to achieve a 26-28% reduction by 2030
- The emission intensity baseline for the sector would need to decrease regularly (e.g. annually)
- This would replace the absolute baseline approach, which implicitly applies under the Emissions Reduction Fund Safeguard Mechanism

Whilst recognising the benefits for customers, *the Roadmap* acknowledges that there appears to be a low likelihood of political consensus around an emissions intensity baseline and credit policy. Consequently, to create a viable policy consensus with the degree of stability required by investors, alternative policy formulations, not considered here, may need to be deployed. Alternative policy frameworks would ideally retain the key ingredients of being market based, technology neutral, capable of reaching the sector's required level of abatement and limiting cost increases to customers.

Milestone 3: By 2026, review opportunities to introduce an economy wide carbon pricing mechanism that is more economically efficient at achieving abatement targets.

A carbon price mechanism would achieve greenhouse gas abatement objectives with the greatest economic efficiency.

Such mechanisms result in higher residential bills over the period 2020 to 2030, which would require careful complimentary financial transfers and compensation agreements to be considered.

Over time, governments should consider options to achieve a carbon price mechanism, including appropriate transfers and without risking subsequent policy churn.

Milestone 4: By 2022 and 2027, adjust Australia's nationally determined contributions to be aligned with achieving the long-term objectives of UNFCCC, COP21 Paris Agreement

The Paris agreement articulates two long term emissions goals, firstly, to reach peak emissions as soon as possible, and secondly, to achieve net greenhouse neutrality in the second half of this century.

The pathway to achieving these reductions requires countries to establish nationally determined contributions and to review their commitments every five years with the expectation that they will show progress beyond the previous ones.

» The mid-2017 climate policy review, should confirm targets for each sector in 2030 and indicate how that target may likely tighten from 2030 to 2050 to accommodate the ongoing strengthening of the nationally determined contribution agreed in Paris

Milestone 5: By 2017, achieve COAG agreement to appoint an independent agency to complete an independent assessment of national energy market implications, including power system security, when developing jurisdiction initiatives on carbon and renewables policy.

Australian governments have recognised the need for better integrated carbon and energy policy.

This is likely to improve the efficiency with which national energy markets achieve abatement objectives and the maintenance of power system security.

To support integrated carbon and energy policy, Australian governments should agree to incorporate an explicit assessment of national energy market implications when developing jurisdiction initiatives.

This assessment should consider the typical energy trilemma issues of energy security, affordability and environmental sustainability.

It should be independent and conducted by an agency such as the Australian Energy Market Commission (AEMC).

Milestone 6: By 2022, complete a review of the effectiveness of Federal Government and State based direct incentive programs that are focused at providing technology specific support for carbon abatement beyond 2020.

The programs or incentives to be reviewed should include state based renewable energy targets and state based energy efficiency targets. The LRET and Small Scale Renewable Energy Scheme would only require review if extended beyond the 2020 targets.

The review should consider:

» The primary objective of the incentive or program

» The cost and benefits of the incentive or program, including both direct and indirect costs and benefits

» Similarities between programs

» Whether the incentive or program is technology focused, and if so, if ongoing support to that technology continues to be warranted or whether the incentive or program should be outcome focused instead

» The timing of the programs or incentive, and potential for amending these programs or incentives to be coordinated by COAG

Key benefits

Contributing to global targets to reduce emissions while lowering the impact on household bills

Introducing an emissions intensive baseline and credit scheme within the power generation sector allows the sector to meet a commensurate emission reduction target of 26 to 28% below 2005 emissions with the lowest impact on residential household bills. The scheme can be introduced by minimal changes to the existing legislation by changing the approach of reducing the absolute baseline to one of reducing the emission intensity across the sector. In addition, generators are able to use a baseline and credit approach to meet the overall emission intensity of the sector.

A stable policy framework is required and over the longer term, governments could consider how to progress from the technology neutral framework to an economy wide carbon pricing mechanism. This will require appropriate transfers and household support.

2017-27 Milestones and actions[7]

	FOUNDATION						IMPLEMENTATION					
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2027+

CARBON ABATEMENT

Secure a stable carbon policy including a trading scheme for generator emissions, enabled by agile network connection and integration of large and small technologies

Review scope for consensus on more efficient carbon pricing, refocus technology specific schemes and increase the Australian international emissions reduction target (2027)

CARBON AND RENEWABLE POLICY OPTIONS

Milestone 1
By 2017, **agree an enduring, stable and nationally integrated carbon policy framework** avoiding the extension of further technology specific incentives

- Complete mid-year review of carbon policy options to reach Australia's 2030 abatement target
- Agree to adopt a national market based mechanism (based on technology neutrality, efficiency and stability)
- Develop the appropriate methodology for allowing a market based mechanism to operate in the power generation sector

Milestone 2
By 2020, commence an **emission intensity baseline and credit scheme** or alternative policy of similar merit to achieve the nationally agreed 26-28% emission reductions by 2030 from the electricity sector

- Introduce an emission intensity baseline and credit scheme or alternative policy of similar merit
- Administer the climate policy
- Comply with the climate policy

Milestone 3
By 2026, review opportunities to **introduce an economy wide carbon pricing mechanism** that is more economically efficient at achieving abatement targets

- Review effectiveness of existing climate policy
- Identify household support and financial transfers required if the existing climate policy is to transition to an economy wide carbon price mechanism
- Introduce modification to the existing climate policy to transition to an economy wide carbon price mechanism
- Develop the appropriate methodologies to support an economy wide carbon pricing mechanism
- Approve transition to an economy wide carbon price mechanism
- Transition to economy wide carbon pricing mechanism

7 Milestone timings are developed as a national guide for Roadmap Implementation. Timing of milestones and actions will differ across jurisdictions and different network areas. Milestone timings are specified as a latest end date, but many will require early action and may be completed earlier than outlined

FOUNDATION						IMPLEMENTATION					
2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2027+

CARBON ABATEMENT

Secure a stable carbon policy including a trading scheme for generator emissions, enabled by agile network connection and integration of large and small technologies

Review scope for consensus on more efficient carbon pricing, refocus technology specific schemes and increase the Australian international emissions reduction target (2027)

CARBON AND RENEWABLE POLICY OPTIONS

Milestone 4
By 2022 and 2027, **adjust Australia's nationally determined contributions** to be aligned with achieving the long-term objectives of the COP21 Agreement

- Sign up to the Paris Agreement (Note: achieved in April 2016)
- Paris Agreement to come into force (Note: achieved in October 2016)
- Review Australia's nationally determined contribution and make adjustments as required
- Review Australia's nationally determined contribution and make adjustments as required

Milestone 5
By 2017, achieve COAG agreement to appoint an **independent agency to complete an independent assessment of national energy market implications**, including power system security, when developing jurisdiction initiatives on carbon and renewables policy

- Gain intergovernmental support for independent assessments on new jurisdiction carbon and renewables policies
- Appoint agency to conduct these independent assessments
- Ongoing assessment of new jurisdiction carbon and renewables policies

Milestone 6
By 2022, **complete a review of the effectiveness of Federal Government and State based direct incentive programs** that are focused at providing technology specific support beyond 2020

- Appoint consultant to conduct review
- Complete review study of technology specific programs by 2020
- Adjust policy settings if warranted

6. EFFICIENT CAPACITY UTILISATION

Background

A combination of new technologies, energy efficiency and structural change in the Australian economy is leading to a flat or declining outlook for electricity consumption. If this projection is realised without any compensating reduction in peak demand, electricity sector capacity utilisation will fall and it will be difficult for the electricity sector to avoid price increases as it recovers the cost of maintaining supply capacity from less delivered energy. At the same time, costs will also be increasing through investments in new low emission electricity generation technologies in line with Australia's emissions reduction target[8].

Alternatively, if capacity utilisation can recover through new demand sources that do not add disproportionately to augmentation of the network to meet new peak demand, there is an opportunity to limit growth in unit prices. While not the only opportunities, electrification of transport and some building services that are currently provided by natural gas were examined as plausible scenarios where electricity consumption could grow strongly relative to peak demand. While not examined here further, prudent re-investment and sizing of infrastructure are certainly among other opportunities for efficient capacity utilisation.

Drivers of change

Growth in global sales of electric vehicles, the increasing numbers of models available, reductions in battery costs, extended vehicle travel range, increased public charging infrastructure, tightening vehicle emissions standards in Europe and the United States and substantial direct subsidies or other incentives offered by a variety of countries and levels of government outside Australia, all indicate increased electric vehicle adoption should be expected over time. There are a growing number of Australian modelling projections providing information on likely timing and quantity. Clustering of projections indicates a central estimate of 20% by 2035 (Figure 11).

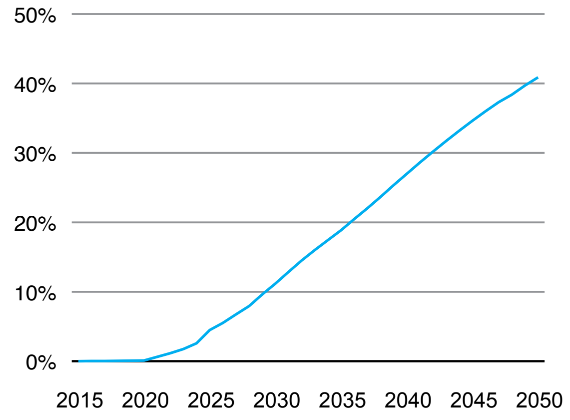
Both gas and electricity prices will be subject to complex trends which could weaken or strengthen the relative competitiveness of their respective household and commercial building appliances. Both have specific non-price benefits. Gas may be increasingly valued as a way to reduce reliance on grid electricity. As greenhouse gas emissions constraints begin to strengthen, natural gas suppliers may look to technologies such as bio-methane, fuel cells and solar gas to strengthen their environmental position.

Electricity is already decarbonising and is likely to be subject to further policy constraints.

Resilient 2027 Future State

- By 2027, opportunities to facilitate the more efficient utilisation of electricity system capacity are maturing, including the electrification of transport, building services electrification and the orchestration of millions of distributed energy resources
- This improved utilisation is helping stabilise the unit cost of electricity for all customers connected to the grid and reduce carbon emissions where low emission generation sources are used

Figure 11: Projected share of electric vehicles in light vehicle road transport – central case



8 COP 21, Paris Agreement, Intended Nationally Determined Contribution

Key findings

The findings for efficient capacity utilisation are summarised below.

Finding 1: Electrification of transport could make a substantial contribution to efficient capacity utilisation

A projection for electric vehicle adoption was developed based on existing studies. The impact of this electric vehicle adoption on the electricity sector was examined under two scenarios:

1. Slow change to electricity pricing and incentives
2. Faster reform of pricing and incentives

In both scenarios, electric vehicles consume an additional 5 TWh of electricity in 2027 and 43 TWh in 2050 (Figure 12). However, while reformed pricing and incentives minimise the impact of electric vehicle adoption on peak demand by encouraging managed charging, slower pricing and incentives reform adds an additional 12,000 MW by 2050 due to a higher degree of unmanaged charging (Figure 13).

Finding 2: Orchestration maximises electric vehicle contribution to decarbonisation and efficient capacity utilisation

While prices and incentives for off-peak charging are a key first step, managed charging of electric vehicles will eventually need to be achieved through some level of orchestration as vehicles begin to number in the millions. Orchestration would ensure there is sufficient diversity of charging responses so that off-peak charging does not create a new peak period.

Figure 12: Projected additional national electricity consumption from electric vehicles

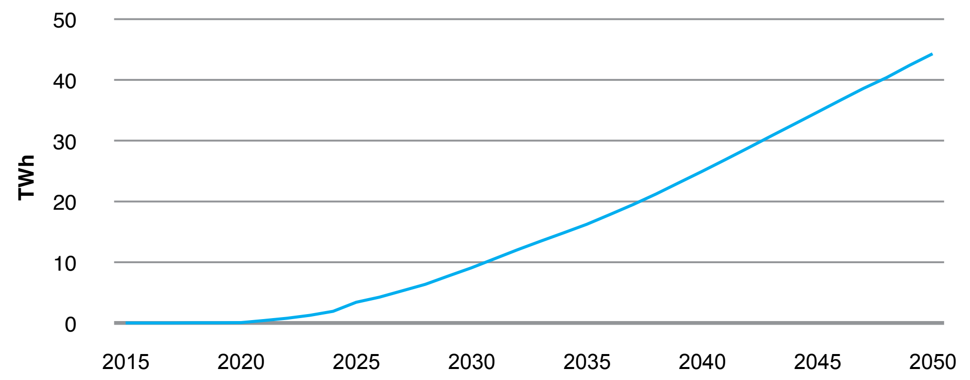
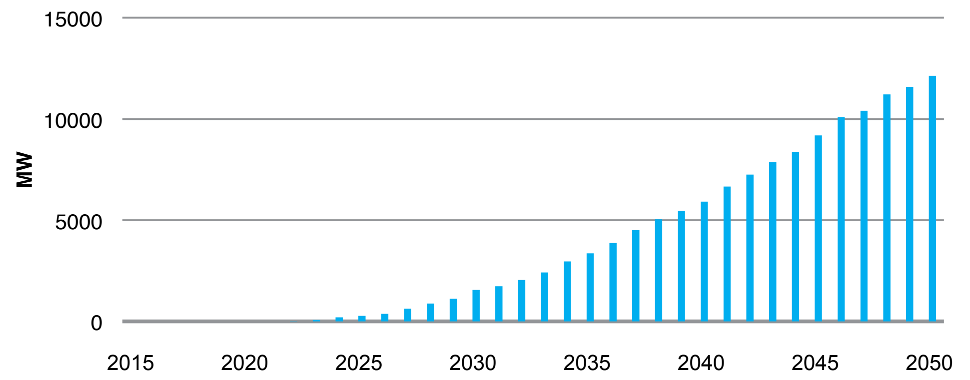


Figure 13: Projected additional national aggregate non-coincident zone substation load from predominantly unmanaged electric vehicle charging



The orchestration of electric vehicle charging has the potential to assist with an increasing need for electricity system balancing, as VRE increases its penetration at both the network and transmission level as part of decarbonisation.

Finding 3: The opportunity for the electrification of building services is less clear

The potential for increased building services electrification is not at all clear from the historical records or the available projections (Figure 14) due to the complexity of changes in drivers for both gas and electricity.

However, if there were electricity consumption growth from this source, it would likely improve electricity capacity utilisation as the additional electricity load would fall proportionally more in winter (e.g. substituting primarily for gas, water, and space heating).

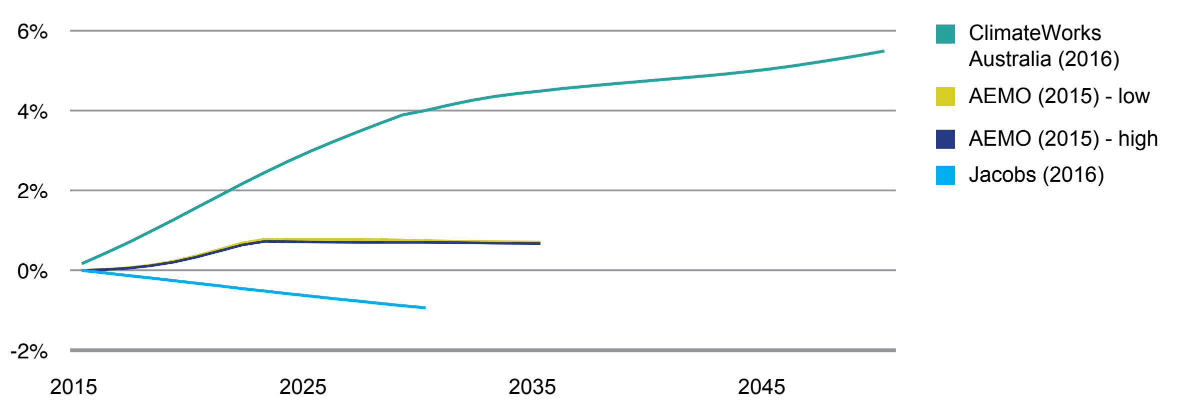
Reference documents

Documents that provide additional background to these findings include:

» Efficient capacity utilisation: transport and building services electrification, Graham and Brinsmead (2016)

» Gas-electricity substitution projections to 2050, ClimateWorks Australia (2016)

Figure 14: Alternative projections of changes in electricity consumption due to competition with gas in building services



2017-27 Milestones

The Roadmap outlines a series of milestones which provide markers of progress over the decade toward the *Resilient 2027 Future State*. Each of the milestones are supported by a series of integrated actions.

Milestone 1: By 2018, implement a light vehicle emissions standard policy, supporting climate goals and electric vehicle adoption

A light vehicle emission standard would provide support for the adoption of electric vehicles because it would eventually encourage the adoption of very low emission vehicle technologies. Electric vehicles have zero tail pipe emissions and electricity generation is expected to continue to decarbonise. A vehicle emission standards policy has the advantage of delivering greenhouse gas reduction in a technology neutral way, and at low cost to government compared to other more direct technology support approaches.

Milestone 2: By 2020, partner to resolve a national approach to electric vehicle charging

Efforts to deliver broad based electricity pricing and incentive reform will be important in maximising the benefit of electric vehicle adoption to the electricity sector and its customers. However, this is not the only pathway to managing electric vehicle charging. The electricity and vehicle industries can, in parallel, begin to determine specific contracting and market offers that may deliver value to all stakeholders. This would represent an extension of the various trials and adaptations of existing contracts for other large loads such as hot water, air conditioning and pool pumps.

Key benefits

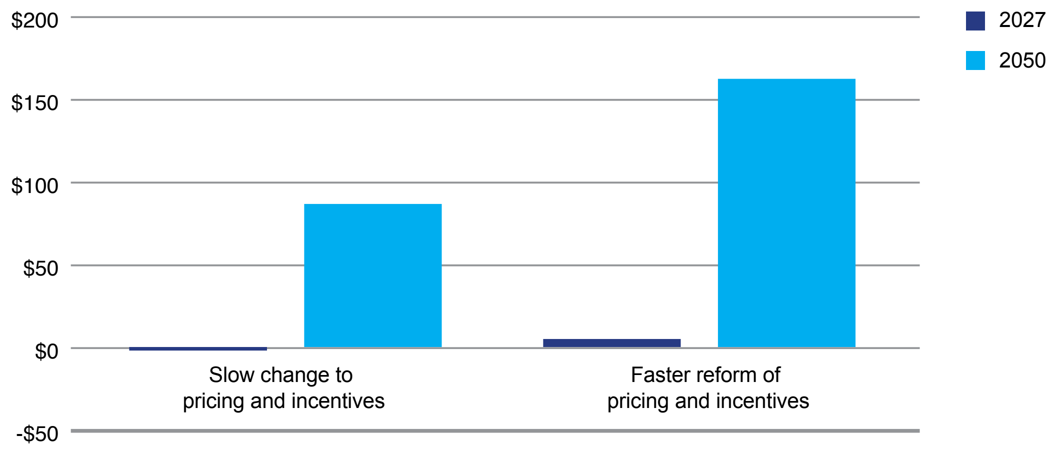
Building services electrification

While increasing electrification of buildings could offer some modest benefits for efficient electricity capacity utilisation, this might be at the cost of a greater reduction in capacity utilisation in gas, due to the disproportionately large shift in gas for each unit of loss of market share to electricity. Consequently, government signals and incentives in energy end use should remain technology and fuel neutral. As such, no specific *Roadmap* milestone is included for buildings services energy.

Transport electrification

Given significant electric vehicle sales is only expected to occur from 2020, electric vehicle adoption has only a negligible impact on residential bills by 2027. However, by 2050, electric vehicle adoption significantly improves capacity utilisation. If electric vehicles are adopted using large (7.2kW) chargers and around half of customers charge in an unmanaged way, average residential electricity bills will decrease by $86 by 2050 (in real terms). However, if customers are given appropriate incentives faster, the electricity sector gets the benefit of increased consumption without as much additional peak demand. In this case, the improved capacity utilisation results in a $162 or an 8% decrease in residential electricity bills by 2050 (Figure 15).

Figure 15: Projected reductions in average residential electricity bills due to electric vehicle adoption under alternative electricity pricing and incentive reform environments



Electric vehicles also deliver a number of co-benefits: reduced direct transport sector greenhouse gas emissions and assistance with system wide load balancing as electricity generation is increasingly decarbonised through VRE penetration; reduced criteria pollutant emissions improving health outcomes; and, improved balance of trade through lower oil imports (holding all other variables constant). Adoption of electric vehicles in preference to internal combustion vehicles is projected to reduce Australian road transport emissions by 22 MtCO_2e per year by 2050.

2017-27 Milestones and actions[9]

	FOUNDATION						IMPLEMENTATION					
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2027+

CARBON ABATEMENT

Secure a stable carbon policy including a trading scheme for generator emissions, enabled by agile network connection and integration of large and small technologies

Review scope for consensus on more efficient carbon pricing, refocus technology specific schemes and increase the Australian international emissions reduction target (2027)

EFFICIENT CAPACITY UTILISATION

Milestone 1
By 2018, implement an appropriate **light vehicle emissions standard policy**, supporting COP21 climate goals and providing an additional incentive for electric vehicle adoption

- (2017) Consider outcomes of the 2016 regulatory impact statement on vehicle emission standards and ensure co-benefits to the electricity sector are included
- (2017–2018) Consider how vehicle emissions standards policy and the road sector in general assists in delivering Australia's greenhouse gas emissions targets, with AEMO to incorporate the findings in their official electricity demand forecasts

Milestone 2
By 2020, partner to resolve **national approach to electric vehicle charging**

- (2017–2018) In collaboration with retailers or other market actors, review incentives systems for encouraging managed electric vehicle charging, irrespective of progress in electricity pricing reform
- (2018) Partner with vehicle industry to present electric vehicle charging incentives at point of sale

9 Milestone timings are developed as a national guide for Roadmap Implementation. Timing of milestones and actions will differ across jurisdictions and different network areas. Milestone timings are specified as a latest end date, but many will require early action and may be completed earlier than outlined

INCENTIVES AND NETWORK REGULATION

A fairer system through active implementation of network tariff and retail pricing reform and modernised regulation and competition frameworks. More customer oriented outcomes are supported, ensuring those without distributed energy resources are treated fairly, while those with distributed energy resources are able to receive incentives for providing network support services that improve the efficiency of the grid for all.

7. PRICING AND INCENTIVES

Background

Electricity pricing is critical to achieving both efficiency and fairness in the transformation of the electricity sector in Australia. Electricity supply remains an essential input to our quality of life at home and the commercial and industrial enterprises that support our economy and jobs. The future resilience of the energy system is also supported through the implementation of a fairer system of prices – one which provides fair rewards and cost recovery and ensures that customers and networks are supported with appropriate regulatory frameworks and mechanisms.

As technology becomes cheaper, smarter and more prevalent, customers will take a lead role in shaping Australia's electricity future. Customers, rather than traditional utilities, are likely to determine more than a quarter of all system investment decisions between now and 2050.

This vast increase in consumer investment in power infrastructure and renewables drives the potential for millions of market actors, including households, to transact energy services and it is expected that dynamic and diverse markets are likely to eventuate. To assist these markets networks will need to prepare for two-way dynamic and de-centralised power flows and the capability for greater transfer of energy to and from different parts of the distribution network.

The incentives issued by network service providers to customers and to third party market actors will be vital to unlock the value of distributed energy resources to enable these markets and services to operate efficiently and reliably.

An efficient adoption and integration of distributed energy resources through appropriate pricing and incentives should deliver significant savings in future network investments. This will include networks avoiding or reducing costs in addressing constraints due to inefficient import or export of energy, while at the same time delivering significant additional value to customers via their ability to participate in other markets.

Failure to transition to a fairer system of prices and incentives will expose customers to the risk of over investment in the system, leading to higher average electricity bills and unfair cross subsidies paid for by some customers.

Drivers of change

A shift towards incentivising efficiency and innovation is being driven by:

- Increased penetration of customer owned generators and electricity storage systems which, if left unmanaged may impact the supply and demand balance in distribution networks, increasing the risk of inefficient duplication of energy investments.
- A growing range of new electricity products and services that can provide immense economic benefits for the community with the right incentives and price signals. This includes products and services which can allow customers or communities to be self-sufficient in their energy requirements or support those who are looking for new peer to peer opportunities.
- The opportunity to harness the potential grid benefits of these new products and services, with incentives for customers to achieve the full benefits of their investments.
- A low take up of more cost reflective network tariffs, even where it can be demonstrated the customer is better off through lower network costs if alternative network tariff assignment frameworks are chosen.
- Expected growth in smart meter penetration which could be accelerated even further to deliver more value for customers, earlier.
- New edge-of-grid capabilities which may allow new customers to receive energy services through lower cost alternatives to grid extension, and opportunities to replace future grid investment with technology alternatives in some communities.

Resilient 2027 Future State

- By 2027, the accelerated transition of customers to more cost reflective tariffs from 2021, supported by the implementation of innovative new pricing options, has improved fairness between customers with and without distributed energy resources
- Customers with distributed energy resources are able to receive incentives for providing network support services that improve the system's efficiency for everyone
- Network businesses are able to connect new customers using standalone power systems as an alternative to traditional grid connections where it is more economic and reduces costs for all network users
- Existing customers and communities with solar PV and energy storage are able to provide some or all of their electricity needs at certain times in exchange for significant network connection cost reductions

Key findings

Key findings were based on an Energeia analysis of the National Electricity Market.

Finding 1: A fairer system of prices can only be achieved in a reasonable timeframe with changes to tariff assignment policy. Existing Australian tariff assignment policy predisposes retailers to continue to assign customers to legacy tariffs unless the customer makes a conscious decision to adopt a different retail product which includes a cost reflective network tariff.

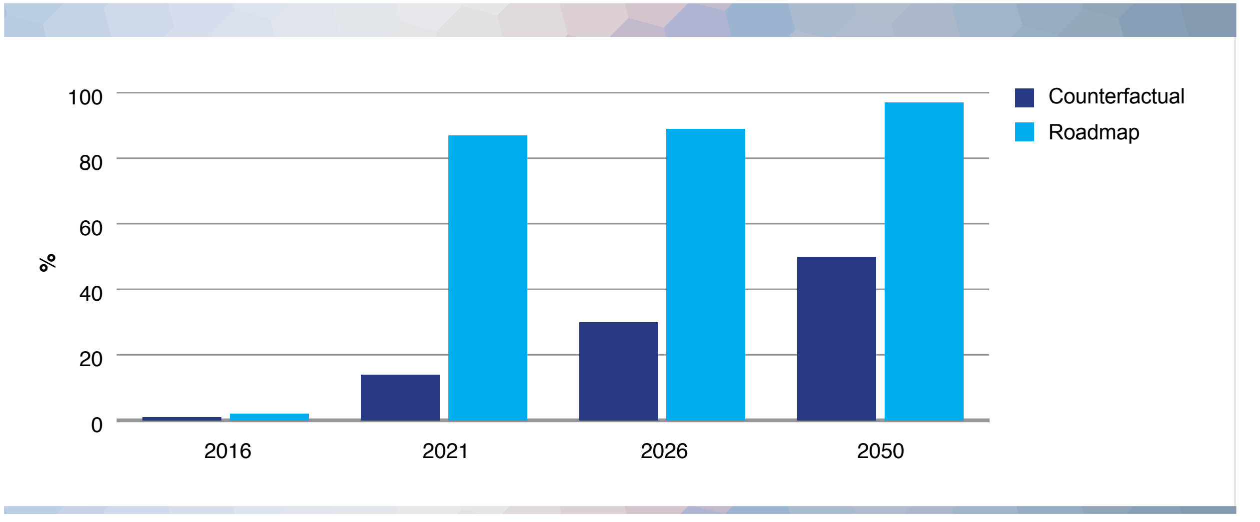
However, waiting for customers to opt-in to new network tariffs fails to achieve timely take up of fair and efficient network tariffs, with 70% of customers remaining on legacy tariffs in 2026 (Figure 16). By contrast, retailers assigning all customers to more cost reflective network tariffs, with a choice to opt-out, results in less than 10% choosing to return to legacy tariffs and results in positive comparative economic benefit of $1.8 billion by 2026.

This is consistent with international studies which conclude that most customers are unlikely to change their pricing arrangements with a retailer, even where it can be demonstrated that they would be financially better off.

Finding 2: Smart meters are essential to ensuring a fair system of prices

There are two clear barriers to widespread adoption of better network tariffs and retail pricing: firstly, the lack of meter technology currently installed in some jurisdictions; and secondly, the gap in tariff assignment policies in those network areas where smart meters are available for use.

Figure 16: Comparison of customers on fair and efficient tariffs



A rapid uptake of smart meter installation in the next four years is therefore essential for the transition to better network tariffs which will enable substantial economic benefits and also remove cross subsidies.

Energeia predicts that under new regulatory arrangements, up to 4 million smart meters will be installed over the next 5 years (Figure 17). However, installation levels will need to be well beyond this projection. Almost universal penetration is required to enable an early assignment of customers to cost reflective tariffs and realise significant economic benefits. Close monitoring by policy makers will be required to ensure market led deployments are effective.

Finding 3: Over $16bn in network savings can be achieved by 2050 through improving existing tariffs, including by introducing new network tariffs and retail pricing options and establishing frameworks for networks to buy grid services from customers with distributed energy resources.

On current projections, investment in battery storage is likely to reach a critical mass before 2030 and without appropriate incentives or orchestration, mass scale battery charging profiles could lead to export/import imbalance in distribution networks or new peak demand events which would drive additional network investment. Refining network tariffs to allow better integration of batteries, as storage technology becomes more affordable and smarter over time would alleviate this risk.

However, there is a real opportunity to unlock further value from customer investments in distributed energy resources through direct, targeted incentive signals. Incentives for network support 'in the right place, at the right time' would achieve an integration of new technologies and complement the more efficient broad-based network tariff structures.

It is recognised that such incentives represent an increased complexity in energy services transactions for small customers. A more 'complex' network incentive need not require active behavioural changes by customers or the direct pass through by a retailer. While a limited number of customers may be willing to engage with such signals through direct response to tariff products like 'critical peak pricing' or 'peak time rebates', behavioural science indicates most will prefer to rely on simplification through automation or intermediaries. Retailers may provide the customer with simple tariff products but support the service with onsite resources which respond to a network incentive, such as a virtual power station. Customers could also participate in demand response programs offered by retailers, aggregators or network service providers leveraging Demand Response Enabled Devices, onsite storage or smart inverters.

Incentives to harness the potential grid benefits of storage provides win-win incentives for customers who want to enjoy the full benefits of their investments while lowering peak demand, improving local power quality and subsequently reducing network investment (see Figure 18).

Figure 17: Forecast penetration of smart meters in Australia

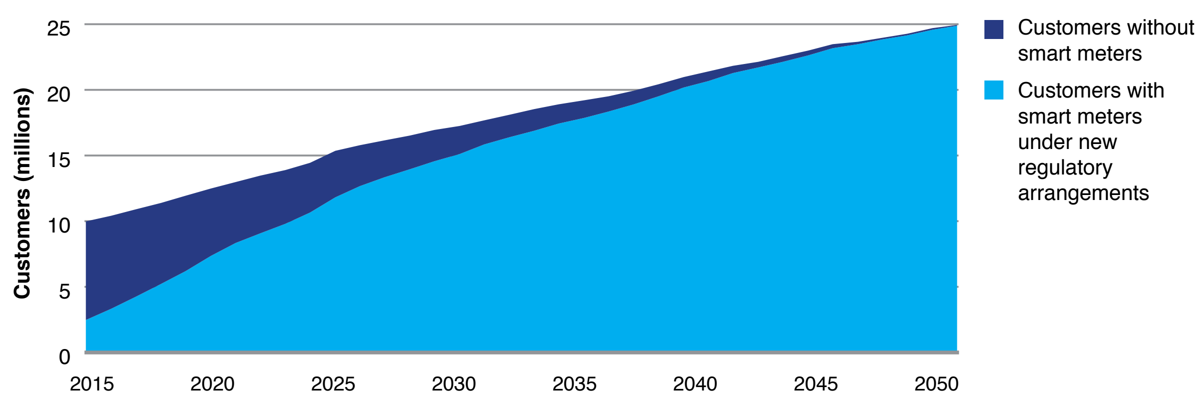
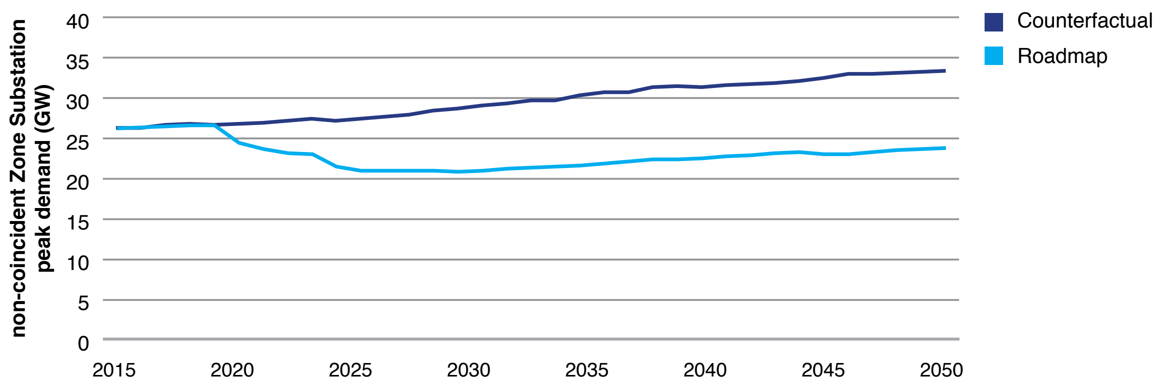


Figure 18: Non-coincident substation peak demand



If implemented correctly, within 10 years, retailers and market actors respond to incentives where up to a third of their customers will participate in the orchestration of their own distributed energy resources, either passively or actively, in order to drive efficient network outcomes. This would include some customers who would otherwise go off grid, being offered incentives to remain on grid with the opportunity to sell distributed energy resources services to the grid and other parties.

Finding 4: In a limited number of circumstances, standalone power systems and micro-grids are likely to become a lower cost alternative to traditional grid supply arrangements over the next 10 years.

Almost $700 million could be saved by supplying these connections, usually farms, with a standalone power system or standalone power systems. Transitioning existing grid connected remote customers to alternative supply via micro-grids or standalone power systems is also likely to result in a lower cost overall in certain circumstances. This can also result in other benefits such as reduced bushfire risk. While this makes sense in theory, current regulations also make the transition from conventional grid supply arrangements very difficult to enact.

For customers in more urbanised areas, the findings suggest there are greater benefits in customers staying grid connected, rather than moving off-grid.

Analysis indicates that without better incentives, up to 10% of customers are likely to leave the grid by 2050, increasing average bills to other customers by $132 per year. Innovative network incentives, like a standalone power system tariff, would encourage over 1 million customers to choose to stay on grid to sell their own distributed energy resources, resulting in lower costs for themselves and other grid customers. This could save those other customers around $1 billion between 2030 and 2050.

Reference documents

Documents that provide additional background to these National Electricity Market findings include:

- Unlocking value for energy customers: Enabling new services, better incentives, fairer rewards, Energeia (2016)
- Unlocking value: Microgrids and Standalone power systems, Energeia (2016)
- DER simulation platform technical report, Energeia (2016)
- Economic benefits of the Electricity Network Transformation Roadmap: Technical report, Brinsmead, Graham and Qiu (2017)

2017-27 Milestones

The Roadmap outlines a series of milestones which provide markers of progress over the decade toward the *Resilient 2027 Future State*. Each of the milestones are supported by a series of integrated actions.

Milestone 1: Early transition to better prices.

By 2021, residential and small business customers are assigned to a new range of cost reflective network tariffs, enabled by a high penetration of smart meters.

The evolution toward cost reflective network pricing and more dynamic market frameworks for grid services will also see a shift from traditional retail pass through of the network tariff structure to a broader range of customer facing products with the right to opt-out, effective customer support and decision making tools, and reforms to government concession schemes.

Milestone 2: New prices for new and differentiated services or to incentivise customer response so as to lower network costs overall.

From 2021, new prices are introduced to reflect new and differentiated services customers want, including self-sufficient supply of energy at some times, and the ability to trade energy on non-traditional platforms (peer to peer arrangements).

Transmission networks may also introduce differentiated pricing in a more dynamic market environment, to better incentivise connections in areas with underutilised network capacity.

Pricing arrangements allow for fair and efficient recovery of costs for the service provided.

Milestone 3: Micro-grids and standalone power systems are a feasible alternative to traditional grid connection

From 2021, networks connect new customers in remote areas (typically 1km or more from the existing grid) with standalone power systems where it is demonstrated to be a lower cost than grid extension. Networks also routinely procure micro-grids, or standalone power systems, as a substitute for traditional delivery models where it is demonstrably efficient and fair to do so.

Milestone 4: Networks buying grid services from customer power systems as an alternative to grid investment.

By 2027, network orchestration using distributed energy resources on a dynamic, locational basis, results in one third of customers selling their distributed energy resources services to networks, directly or through their agents. Dynamic and locational network orchestration of distributed energy resources in many areas provides a lower cost solution to a traditional distribution service expenditure, as it either augments or replaces the existing grid.

Key benefits

Note the benefits below and figures quoted in this Section generally relate to National Electricity Market jurisdictions, excluding Western Australia and Northern Territory. Additional results by jurisdiction, including Western Australia, are available in the technical modelling reports referenced above and in the Regional Modelling outlined in the Appendices.

Better use of smart meter infrastructure

Without actively assigning customers to cost reflective network tariffs, 60% of the smart meters which are projected to be installed for other drivers will remain unused for cost reflective network tariffs in 2050. This would represent a significant lost opportunity to make full use of this enabling $2.7 billion infrastructure.

A faster penetration of advanced metering required to support reforms to pricing and incentives will facilitate other benefits such as remote sensing and better network visibility – essential for ensuring the safe and efficient integration of future large scale variable renewable generation, hundreds of micro-grids and millions of customer distributed energy resources.

Lower network costs and reduced cross subsidies through early transition to better pricing structures

A tariff assignment framework where retailers assign all customers to cost reflective network tariffs, achieves up to $1.4 billion in reduced network investment by 2026 compared to current arrangements, which is equivalent to 10% saving on average network bills. Up to $1.4 billion of cross subsidies from customers without distributed energy resources to customers who have distributed energy resources is also avoided.

More benefits to customers through payments for dynamic and locational use of customer power systems

If networks buy grid services from distributed energy resources customers, this orchestration could replace the need for $16.2 billion in network investment by 2050, while also avoiding future cross subsidies, and lowering average network bills by around 30% compared to today. Even greater benefits are possible for customers over the longer term as the distribution energy services market evolves.

High penetration of customer investment in new technology

These *Roadmap* initiatives support uptake of customer investment in new technology with incentives for investment that better integrates with the existing grid. Under the preferred *Roadmap* recommendations, installed solar PV capacity is expected to increase by more than 400% (20GW) by 2026 as well as 32GWh of battery storage on the network.

Over the following 25 years to 2050, the amount of solar PV capacity would increase almost three-fold again to 72GW with a similar increase in battery storage to 87GWh.

2017-27 Milestones and actions[10]

FOUNDATION						IMPLEMENTATION					
2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2027+

INCENTIVES & NETWORK REGULATION

Incentivise efficiency and innovation through: implementing fair and efficient network tariffs; enabling standalone systems and micro-grids, and; modernising regulation and competition frameworks

Transform efficiency of energy delivery with orchestration of distributed energy resources as networks pay for support in the right place at the right time including use of stand alone systems and customer focussed regulation

PRICING & INCENTIVES

Milestone 1

By 2021, **residential and small business customers are assigned to a new range of cost reflective electricity tariffs**, enabled by a high penetration of smart meters with the right to 'Opt Out', effective customer support and decision making tools, and reforms to government concession schemes

- Review and test alternative peak charging and residual structures with regard to future technological disruption
- Agree to a complete transition from volume based legacy network tariffs to more cost reflective tariffs by 2021-2025
- Regulatory arrangements incentivise trials of up to 1% of customer base to trial alternative customer facing products with new demand based tariffs
- Consult retailers to update tariff structure statements - jointly engage customers, including vulnerable customer trials, for education, support initiatives and concession arrangements
- If applicable change regulatory arrangements so that tariff structures can be amended, if they are more efficient and fair
- Metering co-ordinators provide progress against targets and options for accelerated meter roll out
- Retailers and networks work with regulators on options for accelerated roll out approaches
- Networks consider contingency arrangements for customers who do not have a smart meter but who are assigned to a demand based tariff
- Identify states/NSPs/areas with largest opportunity to gain from migrating to fairer, more efficient demand based tariffs and prioritise meter migration initiatives in those areas

Milestone 2

From 2021, **new prices are introduced to reflect new and differentiated services** customers want to use the network for including 'standalone power system tariffs' for customers with self-sufficient on-site DER

- Develop and evaluate charging mechanisms and rules for Stand Alone Power Systems (SAPS) Tariff
- Consult and Trial SAPS product with priority on networks which can possibly benefit from the earliest adoption
- Identify new services that customers may want to use the network for and consult on pricing arrangements for them

Milestone 3

From 2021, **networks deploy or procure micro-grids or standalone power systems as a substitute for traditional delivery models** where it is demonstrably efficient and fair to do so

- Develop criteria to evaluate demonstration of efficient and fair deployment of microgrids
- Establish current state and preferred future state obligations and responsibilities under pre and post microgrid arrangements
- Assess competition and regulatory issues associated with micro-grid deployment and prioritise regulatory framework amendments if needed
- Develop trial of micro-grid deployment as key learnings for broader scale rollout

10 Milestone timings are developed as a national guide for Roadmap Implementation. Timing of milestones and actions will differ across jurisdictions and different network areas. Milestone timings are specified as a latest end date, but many will require early action and may be completed earlier than outlined

FOUNDATION						IMPLEMENTATION					
2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2027+

INCENTIVES & NETWORK REGULATION

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PRICING & INCENTIVES

Milestone 4

By 2027, network orchestration using DER on a dynamic, locational basis, results in one in three **customers selling their DER services to networks on a dynamic, locational basis**, directly or through their agents

- Networks develop an appropriate framework for procuring operational access on a dynamic and locational basis that would allow proponents to compete for the service requests (2017–2018)
- Regulator funds open trials of procurement frameworks across the NEM to test viability of different operational access platforms (2017–2019)
- Networks develop framework to implement locational & dynamic incentives which act in competition to traditional network augmentation/replacement expenditure or non-network solutions under RiT-D frameworks (2018–2020)
- Networks incorporate framework in next TSS arrangements and engage with key stakeholders on its operation (2019–2021)
- Networks begin offering services and procurement for these services under this framework and work with market actors in its implementation (2020–2025)
- Retailers and networks work with regulators for accelerated roll out approaches (2019–2020)
- Retailers work with stakeholders in how they would include dynamic and locational signals in customer facing products (2024–2027)

8. REGULATORY AND POLICY FRAMEWORKS

Background

Australia's current regulatory model for electricity networks is effectively based on forms of utility regulation developed in the United Kingdom over thirty years ago. It also incorporates some features of US style rate of return regulation that has a history stretching back to the early 1900s. Over time this regulatory model has evolved, for example, with the progressive introduction of a series of incentives, reward and penalties schemes aimed at providing the right signals for capital and operating efficiencies in service delivery, and maintaining or enhancing service quality.

The current regulatory approach is based on network businesses preparing and consulting on detailed regulatory proposals which include expected operating and capital costs, electricity demand, network charges and investment plans for the next five-year regulatory period.

The starting point for the current electricity regulatory model is a presumption of the existence of a centralised one way grid featuring a persistent natural monopoly over critical network services, and limited potential emergence of competition over time. This has led to a relatively intrusive and detailed framework seeking to ensure regulated charges for a narrow and defined set of regulated services reflect efficient costs. A further goal has been providing a predictable cost recovery framework to provide network investors the confidence to continue to make substantial ongoing investments in long lived capital intensive network assets such as poles and wires.

A regulatory framework with these characteristics is unlikely to represent the optimum framework to promote the long-term interests of consumers, or to protect the medium term commercial interests of the network sector as it evolves.

Drivers of change

The evolution of the electricity grid to integrate complex and diverse customer needs and distributed energy resources will challenge the traditional regulatory framework. The widespread diffusion of distributed energy resources, in the form of large scale embedded generation, increasing penetration of solar PV, and the potential emergence of mass scale battery storage technologies will have significant implications for the future of economic regulation.

Some key drivers that are relevant for regulatory and policy framework development include:

- Emergence of new technologies and new business models, providing capacity for greater competition and service tailoring
- The potential for the development of off grid solutions and competition in a range of traditional network services to lead to an unplanned and disruptive break down of the funding of the commons of a shared network service capable of integrating efficient levels of centralised generation and distributed energy resources that meet customer needs
- The potential for the regulatory framework to unintentionally stifle delivery of customer valued services by a variety of competing business models, operating on a level playing field to deliver value

Resilient 2027 Future State

- By 2027, customer interests are protected by vigorous competition between an active set of commercial players with the opportunity to deliver enhanced customer and commercial value through building and seeking out economies of scope and scale
- A lighter handed framework of economic regulation is applied to a reduced set of services, enabling greater flexibility and innovation while delivering outcomes that - because of an alignment of incentives - benefits consumer and networks interests
- Where common assets underpin the delivery of these services (and universal service obligations), they are efficiently funded through a well-understood, stable regulatory compact

Key findings

Finding 1: Opportunity for consumer centric frameworks

There is the opportunity to move to more of a consumer centric, and less of a regulator driven framework. In previous regulatory models, the regulator has been in effect required to act as a proxy for consumers in determining what services should be available and for what price. New models provide the opportunity to move away from this approach. This can include, for example, so called customer settlement approaches which have been trialled in other sectors and internationally (such as the water sector in the United Kingdom). It can also encompass networks actively proposing direct outputs that are valued by customers, an approach being adopted in the UK energy sector under the so-called *Regulation Innovation Incentives and Outputs* approach.

This finding reflects that a central core set of network services will continue to require some form of monopoly regulation, even if this looks different to what we have today, and covers fewer services.

Finding 2: Lighter handed models may be more feasible

Alongside reformed consumer centric frameworks, there is also the opportunity to move to lighter handed regulatory models, especially for services which are increasingly subject to competitive disciplines. This means options such as information disclosure regimes, monitoring or price caps in some areas may be more feasible in the future. Such approaches provide a possible menu of types of regulatory oversight that provide for protection of customers' interests in periods of dynamic changes in markets, or where policy makers have confidence that competition can be partially relied upon as a means of protecting customers' interests.

Cambridge Economic Policy Associates, in expert advice to *the Roadmap*, have suggested the strong potential for TOTEX (Total Expenditure – both capital and operational) based approaches. These TOTEX approaches assess regulated networks proposed expenditures in a more holistic manner to benefit customers.

Finding 3: Role for tests of emerging competition

Competition tests – and the threshold for where more intensive and costly economic regulatory approaches apply – will need closer consideration and design as competition for network services strengthens. As the scope for competition for network services expands, the regulatory regime will need more dedicated mechanisms and processes to recognise and define the boundaries of regulation and competition.

Accompanying this, as recognised in Sections 10 and 11, the regulatory framework will need to define and accommodate potential approaches to developing distribution system roles and responsibilities.

Finding 4: Framework needs to be flexible to new services

A range of services may become completely contestable, changing the monopoly regulation presumption. A framework will need to have flexibility in incorporating new service types while continuing to support long lived investments. This development is already evident in a range of rule changes and rule based reviews being considered by current policy makers and energy market bodies, such as the Australian Energy Market Commission (AEMC).

Reference documents

Documents that provide additional background to these findings include:

- Future regulatory options for electricity networks, Cambridge Economic Policy Associates (August 2016)

2017-27 Milestones

The Roadmap outlines a series of milestones which provide markers of progress over the decade toward the Resilient 2027 Future State. Each of the milestones are supported by a series of integrated actions.

Milestone 1: By 2018, the customers' role is central to regulatory processes covering core regulated services for agreeing network outputs and risk allocation.

This milestone is aimed at reaching reformed regulatory determination processes which are based around the needs of current and future consumers, and which provide for a clear and agreed allocation of risks between consumers, networks, and other participants. These customer centric processes should aim to deliver those outputs most valued by consumers.

Milestone 2: By 2018, structured trialling of alternative regulatory approaches is well advanced, including customer settlement approaches, as well as TOTEX trials. TOTEX is adopted as default approach by 2027.

Alternative regulatory approaches which are less resource intensive, and which provide better incentives are an important area for further exploration. Under a TOTEX approach, regulated networks would be given a single operating and capital investment allowance, driving least cost outcomes for consumers, and removing any potential bias towards expensive capital investment solutions. TOTEX would also better align incentives between customers, networks and third party providers in the deployment of efficiently scaled distributed energy resources.

Opportunities for limited trials of alternative regulatory approaches would need to be aligned with specific network needs given the inherent transaction costs of adapting to new frameworks.

Milestone 3: By 2019, new regulatory frameworks that are more adaptive to emerging competition are implemented (i.e. tests for whether regulation is needed, shifting services out of regulation).

Past regulatory frameworks for electricity were designed for where competition was the exception, rather than current markets that see competition emerging across many network services. A regulatory framework that efficiently tests and checks the amount of regulation needed for each service and market is key to delivering the benefits of competition to the widest number of consumers. This framework needs to be integrated with other elements of the regulatory framework, such as those governing the scope of services, and shared network revenue setting provisions.

Key benefits

Customer focused regulation

A more responsive and customer need focused regulatory system will create greater empowerment of customers and choice, leading to better realisation of customer preferences.

In addition, there will be benefits from reduced distortion of energy markets and related markets arising from regulatory interventions that substitute for market forces and customer choices.

Aligning risk allocation and defining the regulatory compact

A further benefit arising from trialling new regulatory approaches is likely to be even more efficient investment levels, and reduced energy input costs arising from a stable and genuinely community owned risk allocation bargain. Fairer outcomes across customers should occur through equitable sharing of universal service costs.

In addition, customers will benefit from

» increased network reliability, resilience and capacity to serve arising from optimum distributed energy resources deployment

» greater peer based competition to serve customers and achieve efficiencies

2017-27 Milestones & Actions[11]

FOUNDATION						IMPLEMENTATION					
2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2027+

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REGULATORY AND POLICY FRAMEWORKS

Milestone 1
By 2018, the **customers' role is central to regulatory processes** covering core regulated services for agreeing network outputs and risk allocation

- Explore the potential to add a dedicated 'fast track' regulatory process into the Law and Rules as an alternative to the full existing determination process
- Consultation on AER/AEMC long-term risk allocation guidance statement
- From 2018, move to wider 'routine use' of full fast track processes, with consumers signing-off on a range of network proposed outputs they value

Milestone 2
By 2018, **structured trialling of alternative regulatory approaches is well advanced**, including customer settlement approaches, as well as TOTEX trials. TOTEX is adopted as default approach by 2027

- Trial customer settlement' process on single network decision and, if successful, increase consumers' role vs regulators
- Move wider to wider routine use of customer settlement processes
- Assess the rules which would need to change: depreciation, RAB roll-forward, OPEX, CAPEX, capitalisation rules
- Introduce rules that allow for testing of TOTEX without requiring initial wholesale changing of the framework (a 'sand-box approach')
- Test TOTEX use for a set of businesses on a trial voluntary basis as part of a single price control cycle
- Adoption of TOTEX model as default

11 Milestone timings are developed as a national guide for Roadmap Implementation. Timing of milestones and actions will differ across jurisdictions and different network areas. Milestone timings are specified as a latest end date, but many will require early action and may be completed earlier than outlined

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REGULATORY AND POLICY FRAMEWORKS

Milestone 3

By 2019, new **regulatory frameworks that are more adaptive** to emerging competition are implemented (i.e. tests for whether regulation needed, shifting services out of regulation)

- Develop competition tests for introduction into the regulatory framework, which assess network operators' scope for competing and allow for competition to develop (2017–2018)
- Develop workable mechanisms for movement of network services between regulated and unregulated status (2017–2018)
- Develop improved 'light handed' regulatory models for services not requiring full access regulation, but not competitive (2018–2019)
- Reach revised law and rules framework for recognising emerging competition (i.e. new institutional roles and law/rules in operation) (2019)

POWER SYSTEM SECURITY

Electricity networks and the power system as a whole are enabled to support an expanding diversity of energy sources, at both the customer and transmission levels of the system. System safety, security and reliability are a central focus and customer distributed energy resources are enabled to become an integral part of network optimisation and whole-of-system balancing.

9. POWER SYSTEM SECURITY

Background

Achieving high levels of power system security and reliability is a fundamental requirement for the future of Australia's electricity system. Due to changes to the generation mix connected to the transmission system, and the resulting challenges for system security, a key objective of *the Roadmap* is to achieve transformation of the transmission network to ensure that it enables the required transition to a low emission generation future while delivering high levels of energy security and reliability.

The current transformational change has included a significant rise in the connection of renewable electricity generation at the transmission level, as well as distributed energy resources. Some modes of renewable generation exhibit a range of technical characteristics (e.g. weather dependent intermittency, periodicity, low stabilising inertia) that need to be managed by using new approaches.

This transition is also leading to the withdrawal of traditional centralised synchronous baseload generation and changing consumer demand being displaced by non-synchronous generation at both the utility scale and the residential level.

The speed in which the industry is rapidly evolving is adding a new dimension to the challenge of managing and coordinating Australia's power system in a way that both meets and benefits customer's new needs and requirements, without risking system security.

The transmission network must be transformed to ensure it can successfully integrate a diverse range of generation types, potentially localised within a region. This will involve a reconsideration of traditional planning, control and operational strategies, and may involve the deployment of new innovations in plant and equipment.

To ensure the security and reliability of the NEM, it is critical that innovative solutions are found to better facilitate the integration and management of distributed energy resources, and the rise in active consumer response to provide effective management of the interface between the distribution system and the wholesale market. This involves the development of forecasting and control techniques that provides the market operator timely information and the potential to control outcomes.

Drivers of change

The following key issues are driving changes to the traditional operational characteristics of the power system with the potential to impact its stability and security.

- **Key driver 1:** Government policy settings to encourage the development of renewable energy sources, are changing the mix and characteristics of electricity generation sources (i.e. the shift from central synchronous generation to numerous smaller distributed non-synchronous generation).
- **Key driver 2:** Customers are becoming more engaged in how their energy needs are met, resulting in increasing amounts of distributed energy resources, such as rooftop PV, leading to significant levels of volatility at the point of connection between the distribution networks and transmission connection points.
- **Key driver 3:** The changes and increased complexity of the electrical characteristics of all components of the power system are changing its dynamic behaviour and rendering some traditional operating and control approaches inadequate and obsolete.
- **Key driver 4:** The reduction in suppliers of traditional ancillary services is reducing the level of response available to secure the system and decreasing the efficiency of a market response as a result of concentration of market power.

Resilient 2027 Future State

- By 2027 Australia's power system is agile in the identification of and response to the changing requirements, mix and characteristics of electricity generation sources, while also protecting energy security, reliability and quality of supply
- The multiplicity of grid connected power sources are actively balanced at both the high voltage and low voltage level in the power system to ensure system stability is not compromised and high levels of security are maintained

Key findings

To deliver this section of work a formalised collaboration was established with the Australian Energy Market Operator (AEMO) based on the synergies between *the Roadmap* and AEMO's Future Power System Security (FPSS) program. This was supplemented by work undertaken by EA Technology, who were commissioned to determine the features and characteristics of the future grid side architecture including implications on system security; and modelling work undertaken by CSIRO.

Finding 1: High priority challenges

The AEMO FPSS program focused on identifying and understanding the underlying technical challenges to power system security, ensuring that they were expressed as fundamental properties of the power system. The four key technical challenges identified were:

» Frequency control

» Management of extreme power system conditions

» Visibility of the power system (information, data, and models)

» System strength[12]

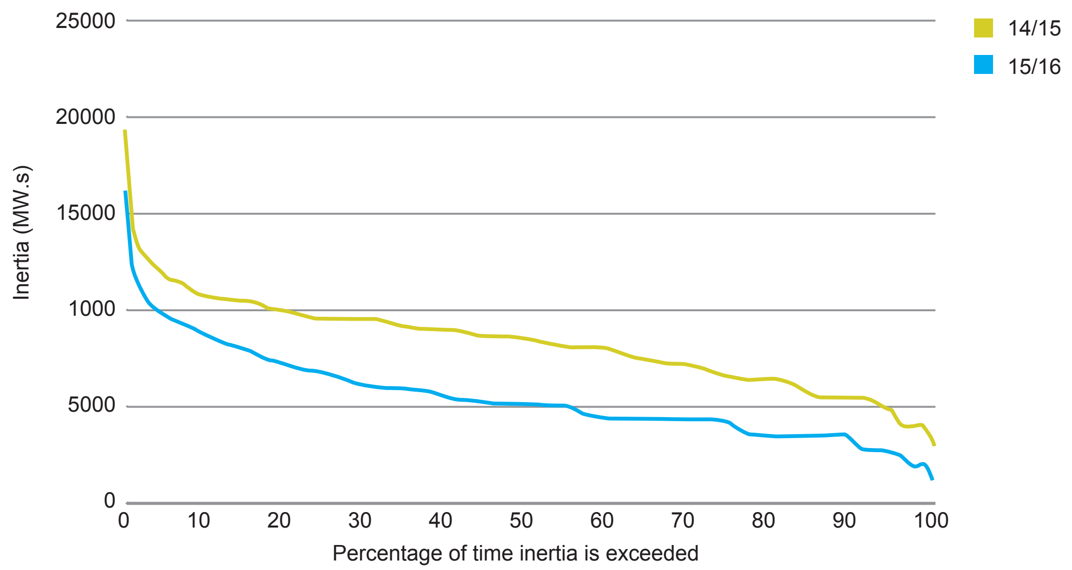
Frequency control

It is essential that the power system operates in a secure state at all times. This is possible if the system has adequate inertia to maintain the system frequency within limits in the event of a contingency, or if Rate of Change of Frequency (RoCoF) can be managed by frequency response mechanisms. RoCoF also can be managed by limiting the impact or exposure to a contingency; which may be possible by management of generation, or by augmentation or configuration of networks, where these options are economic.

Supply and demand imbalances due to any contingency will cause larger and more rapid frequency deviations that will be increasingly hard to manage in a low inertia system.

Figure 19 illustrates the decline in inertia in South Australia over the 2014/15 and 2015/16 years. As inertia is a macro feature, shared between NEM regions, this reduction does not affect stable operations provided that the Heywood Interconnector is in service.

Figure 19: Changes in system inertia in South Australia (Source: AEMO)



12 System strength refers to the inherent stability of a power system and is usually assessed by fault current contribution and voltage stability

However, should South Australia be islanded from the rest of the NEM, lower inertia would result in greater RoCoF from load or generation events.

AEMO found that if the Heywood Interconnector was impacted by an unexpected trip during a period when at high power flow, it could cause a significant event for the region, as it would create a large mismatch between supply and demand, and could lead to South Australia becoming islanded.

Given the decline in inertia across Australia's power system, AEMO has been continually monitoring the state of the power system to assess how frequently the highest risk components of the system are exposed to high levels of RoCoF following a non-credible separation event.

The AEMO FPSS findings indicated that no shortfall is anticipated in the immediate future, unless:

» A significant growth in utility scale variable solar photovoltaic or wind generation occurs, particularly if it is concentrated in one region.

» There is a significant retirement or loss of regulation ancillary service providers, without new entrants to replace them.

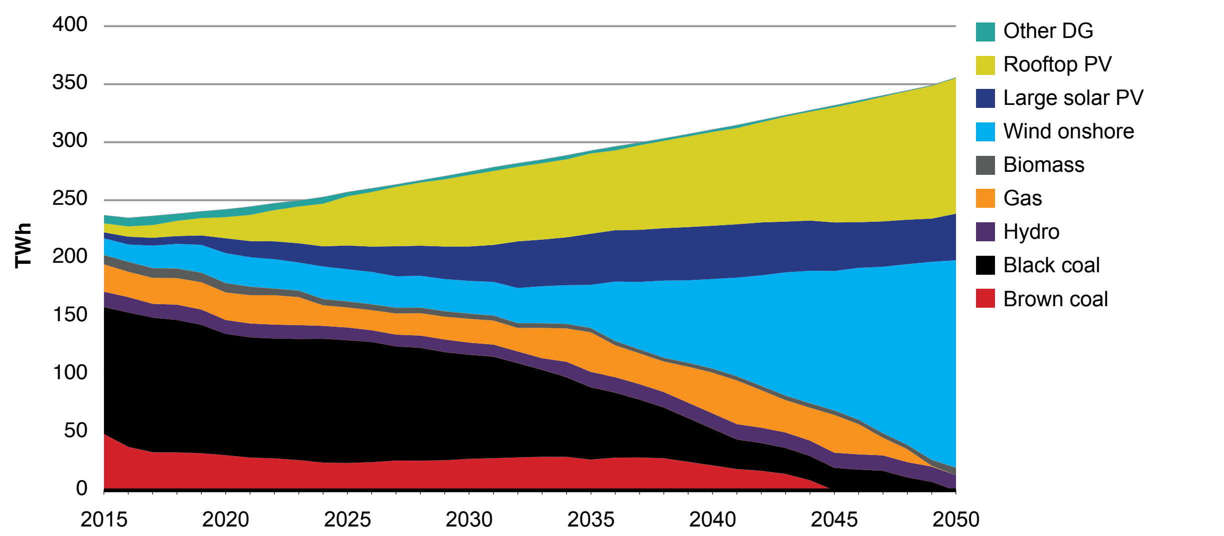
Energy system modelling undertaken for *the Roadmap* identified the generation mix as summarised in Figure 20, as a plausible projection of generation sources required to meet wholesale energy requirements and zero net emissions by 2050. The analysis assumes a primary role for storage in balancing the output of variable renewable energy (VRE) as a feasible solution, but recognises that a range of solutions may be employed.

The generation modelling is not intended to be an optimised analysis of comparative technical solutions to achieve a wholesale portfolio scenario, and ultimately each NEM region will need to consider all of the possible combinations of solutions.

While battery storage is forecast to provide the dominant new source of energy balancing, there are a diversity of potential solutions which could be employed as alternatives while still achieving zero net emissions depending on their changing economic potential.

For instance, some of the other options for energy balancing which may provide such solutions in a low or zero net emissions system include: renewables diversity (technological and geographical), 'pumped hydro' storage, 'Power to Gas' hydrogen storage, concentrated solar thermal generation or gas-fired generation supported by carbon capture and storage (CCS) technology, firm (dispatchable) renewable capacity and demand management.

Figure 20: Electricity output by generation type to 2050



The current wholesale market modelling supports the view that a zero net emissions objective can plausibly be pursued and has been developed to identify the key Roadmap milestones that would need to be taken to equip the network sector to enable this future. *The Roadmap* has not resolved these issues but identified the critical elements to be progressed in the next 10 years if there is to be a reasonable prospect of deep decarbonisation by 2050.

It is recognised that power system security with this generation mix, with very low levels of native inertia will require careful analysis of system stability and security risks during the transition of the generation portfolio. Energy system modelling undertaken to date does not evaluate system security at a granular level specific to individual NEM regions. Such 'stress testing' analysis of system strength and credible contingency events would be required and is a recommended part of the work program identified in *the Roadmap*. A range of technical solutions exist to achieve inertia and frequency management outcomes, including the use of synchronous condensers, rotational stabilisers, large scale batteries, flywheel technology and emulated inertial responses from, for instance, super-capacitor technologies or wind turbines by using the kinetic energy to support the frequency by interchanging this energy with the grid.

Additionally, the distribution system is also a potential source of new ancillary services to support transmission-level system stability. New sophisticated control systems will allow inverter connected devices to set and maintain frequency, enabling genuine replacement of synchronous generation in large network systems.

Management of extreme power system conditions

Management of frequency under extreme or emergency events is becoming more significant for the NEM. Lower levels of synchronous generation, during non-credible contingency events could result in high RoCoF that will be harder to manage with the current emergency frequency control schemes.

As the generation mix changes, new standards for minimum levels of inertia and system strength may need to be specified for the power system to ensure that the required levels of system security are maintained.

Power system visibility

The rapid changes to the traditional operational characteristics of the power system is also impacting AEMO's ability as the system operator to accurately determine the technical envelope and operational limits of the power system. This is being caused by customer driven increases in distributed energy resources technologies including volatile generation and load control embedded deeply within the distribution network.

The consequences of this is that the demand at the transmission connection points is volatile, and AEMO has very little visibility of the potential size and changeability of this for operational purposes. This results in power system and market operations are becoming increasingly more difficult to manage efficiently.

To resolve this issue, frameworks and systems aimed at providing improved real time information and forecast future behaviour are essential at the interface between the Transmission System Operator (TSO) and the distribution system.

System strength

Power systems with a high quantity of on-line synchronous generation and low levels of non-synchronous connected generation provide larger fault current and are categorised as strong systems. Reduction in system strength has been observed in certain parts of the power system due to the loss of local synchronous generation. No current challenges to power system security related to reduced system strength have been identified, however this issue is expected to become more significant as the generation mix continues to change and include higher levels of non-synchronous generation. This could potentially impact the ability of the power system to maintain stability in response to various types of disturbances.

System strength is usually measured by the available fault current at a given location. Higher fault current levels are typically found in a stronger power system, while lower fault current levels are representative of a weaker power system. Low fault levels on the power system can reduce the effectiveness of protection systems as it makes it more difficult to discriminate between the currents that flow in normal operation from those that occur during a fault. Low voltage levels may also result in greater difficulty in maintaining stable voltage levels in some parts of the network.

As a consequence, it will be necessary to develop new protection and control approaches to cater for these changes. This is possible as technologies are now available that provide greater functionality to deal with these issues compared to more traditional protection equipment which has inherent limitations.

» A range of new mechanisms will be required to ensure that the security of the power system is maintained as the sources of generation change at both the transmission and distribution level. These changes include:
  - new operational standards that specify minimum values of inertia and system strength to be maintained in the power system at all times
  - ensuring that AEMO is able to acquire additional inertia or fast frequency response as required to maintain system security
  - standards may also be able to be imposed on new connections to ensure provision of capability to support system security
  - new technological approaches may be employed, for example new protection and control methodologies with different equipment may be necessary to address the issues arising from lower fault levels arising in the main transmission networks

Finding 2: Multiple combinations of strategies will be needed

There are many options to meet future energy balancing requirements, for example:

» additional transmission and state interconnectors

  Further investigation of interconnector feasibility may identify areas where system security could be improved by connecting areas containing low levels of inertia with a region containing a high level of on-line synchronous generation (high levels of inertia), thus reducing the likelihood of a system disturbance leading to a major disruption to electricity supply. Interconnectors and transmission links can:
  - connect renewable generators in new areas by providing geographic diversity.
  - facilitate greater competition between sources of generation and thus deliver better prices for customers, by allowing increased access to a range of power sources, as well as opening up access to the market for more renewable generation developments

» requiring or contracting minimum levels of conventional generation to operate in addition to lower emission conventional sources such as pumped storage or gas fired generation

» storage such as batteries and hydro

» renewables diversity (technological and geographical)

» an over-build of variable renewable generation

» firm (dispatchable) renewable capacity and demand management

To meet sub five-minute power quality issues, a variety of possible solutions have also been identified including:

» conventional spinning reserve

» advanced inverters

» synchronous condensers

The following projected analysis of the South Australian system at 80% renewables in 2036 shows how some of the energy balancing solutions could work together over a twelve month period. These charts show three days for both the summer (Figure 21) and winter (Figure 22) seasons.

In the example shown for summer (Figure 21), excess energy will be produced in the middle of the day, some of which is transferred to battery storage. Overnight demand is met from battery storage, in combination with some baseload, peaking gas and a small amount of dispatchable biomass.

Figure 21 also indicates that on the third day it remained sufficiently windy overnight (green), which allowed for renewable diversity to meet the energy balance on that day without the need for other capacity.

In Figure 22, winter renewable output in 2036 can be observed as being lower than during summer, and as such the system producing less energy for battery storage during the day. This results in the system needing to utilise gas peaking plant much more during this period. It should be noted that this example could be modified to include other solutions such the deployment of further demand management or state interconnectors.

Figure 21: South Australia 2036, 80% renewables, three sample days, summer

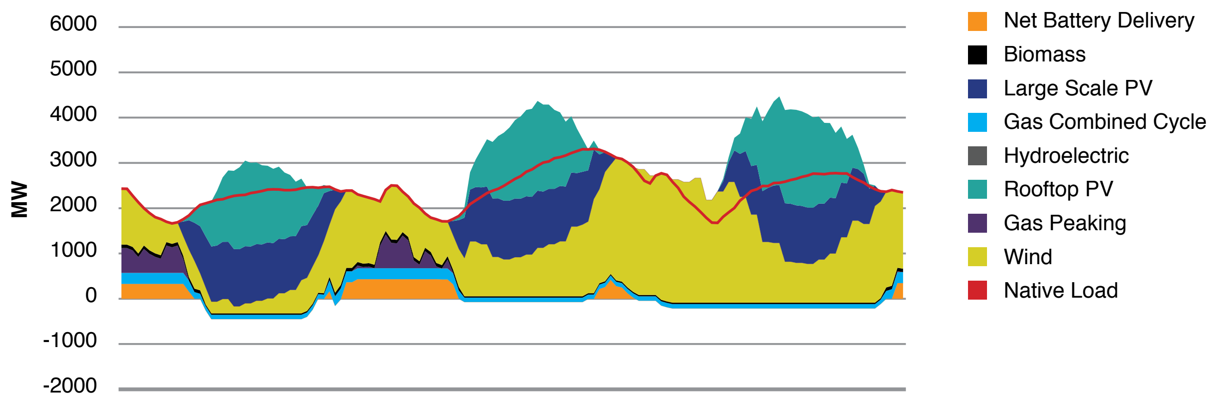
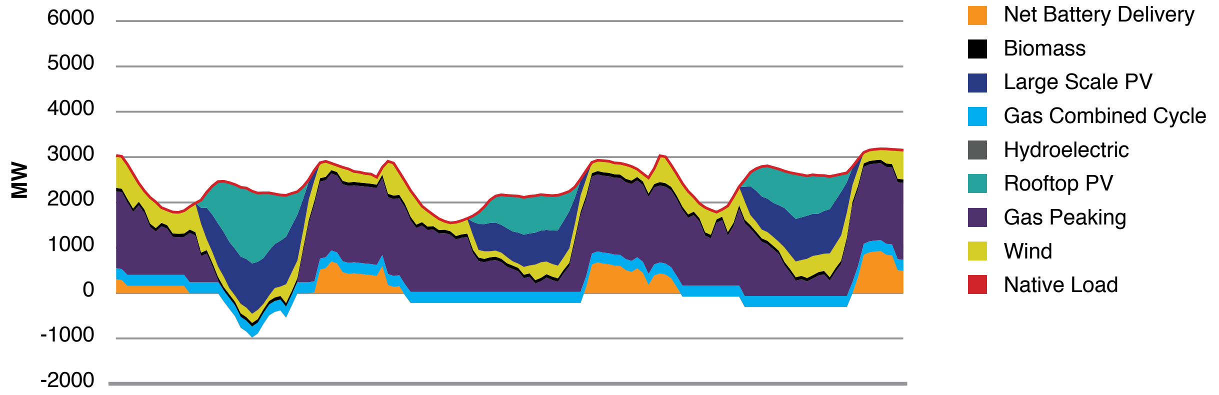


Figure 22: South Australia 2036, 80% renewables, three sample days, winter



This example ultimately demonstrates that individual NEM region balancing is unlikely to rely on one single strategy or solution but will need to consider all possible combinations of solutions to provide a secure and reliable power system.

As more low emissions generation is installed, and in the absence of sufficient alternative strategies, consideration should be given to the needs of each NEM region. This includes if there is a need to specify a requirement for provision of firm capacity to meet the system security needs - the amount needed to deploy to support variable renewables in specific circumstances.

Finding 3: New forms of system architecture can be adopted to provide system security

New forms of network system architecture will be employed to reengineer the overall system to incorporate the diversity of future connected equipment and to provide the platforms for effective customer interaction. This architecture may be designed to assist in meeting power system security needs. Examples where this may occur are:

» **Active network management:** Far greater levels of monitoring and control will be required to allow active management of the distribution network to meet its increasingly complex operational needs. This will require consistent, open and flexible systems, with suitable communications and open standards to permit new market entrants to participate. This decentralised intelligence should be developed to operate as an integral component of a hierarchical control scheme that facilitates effective control, functionality at higher voltage levels and assists in providing additional flexibility and control functionality at the interface with the transmission network and the wholesale market.

- **Network visibility:** All future scenarios indicate the involvement of third parties in a variety of roles interacting with the grid in real time, responding to price signals or operational incentives. This functionality requires real time access to monitoring data, giving rise to the requirement for a cheap, reliable and open data, monitoring and communications platform. This platform can be used to provide various data, including operational data that may assist in providing more transparent information to AEMO on the real time and forecast operation of the distribution network interface.
- **Protection methods:** Today's methods for network protection will become increasingly unsuitable for all the future scenarios. Protection based around sensing of RoCoF will become unstable as system inertia reduces and larger (non-fault) variations in frequency are commonplace. As previously noted it will be necessary to investigate and trial alternative protection mechanisms that exhibit better stability, such as frequency-forcing, where grid parameters such as frequency variations and voltage dips are more commonplace.

  In addition, consideration could be given to entirely new forms of protection, by incorporating it as a component of an integrated control and monitoring architecture which will become increasing feasible and effective with the implementation of new technologies and platforms.

  Successful development and implementation of these new forms of protection could achieve a range of objectives in transforming the networks. By ensuring power system security is maintained, protection systems facilitate the connection of diverse new technologies, including renewables.

A more detailed description of the future grid architecture requirements needed to provide the new functionality required to deliver services and products is described in Section 10 Grid Transformation.

Reference documents

Documents that provide additional background to these findings include:

- Future Power System Security Program: Progress Report, AEMO (2016)
- Economic benefits of the Electricity Network Transformation Roadmap: Technical report, Brinsmead, Graham and Qiu (2017)
- Electricity Network Transformation Roadmap: Grid design, operation, platform & telecoms report, EA Technology, (2016)

2017-27 Milestones

The Roadmap outlines a series of milestones which provide markers of progress over the decade toward the *Resilient 2027 Future State*. Each of the milestones are supported by a series of integrated actions.

Milestone 1: By 2018, the central and transformed role for the transmission system to support power system security has been defined.

A range of new analytical tools to extend current power system forecasting and planning approaches, will enable networks to work with all key stakeholders to undertake robust and comprehensive long term regional planning for transmission infrastructure.

Transformation of the transmission system by developing new operational techniques and measures for dealing with variable generation resources, combined with appropriate new market mechanisms for services will assist in ensuring that the transmission system plays a key role in addressing current issues relating to power system security in the NEM.

Specifying the requirements for the transmission system to maintain high levels of system security as conventional synchronous generation is replaced with renewable energy sources on frequency control is a key step for planning the move to zero net emissions generation future. Detailed power system security analysis to investigate the requirements for the transmission system, including the additional controls and frequency support mechanisms will be carried out to provide a robust specification for the future transmission system.

Milestone 2: By 2018, market based approaches for providing efficient capacity, and balancing and ancillary services have been established, including a set of fully tested options that would cater for a very low emission generation mix.

The increasing penetration of VRE sources and loss of synchronous generation will require revision of existing market frameworks and technical regulation to ensure system security is maintained. Effective market-based approaches can be developed to provide assurance of capacity, balancing and ancillary services important to system security. There is likely to be the need to augment existing defined service markets in the NEM, to ensure previously inherent services, such as inertia or fast frequency response, are explicitly identified, and secured. This is likely to require detailed scenario analysis of potential sources of balancing services as well as an expanded set of 'ancillary' services, to provide more granular stress testing, by NEM region. This analysis would identify the feasibility and cost of maintaining system stability while achieving the long-term abatement objective of zero net emissions.

Milestone 3: By 2019, an initial approach has been developed for coordinating and optimising decisions across the power system as a whole, which includes more effective interfacing between the Independent Market Operator (IMO) and the distribution network connection points.

Communication between the IMO (Independent Market Operator) and distribution system control functionality in real time using automated signals is critical if coordination and optimisation of the system is to be achieved.

Developed in consultation with all relevant stakeholders, the scope of, and access to, information at the interface between the transmission and distribution networks will be required to allow for enhanced intelligence and decision making tools to operate effectively to ensure optimal power system coordination.

This will need to be supported by enhanced hierarchical control strategies embedded within the distribution system to assist in meeting information and control functionality requirements at the interface.

Milestone 4: By 2020, new tools and models have been developed to provide better forecasting to better anticipate where environmental and system constraints could lead to system security issues.

A range of new operational models and techniques to enhance reliable forecasting of variable renewable generation and distributed energy resources are crucial in achieving better predictions of where environmental and system constraints could lead to system security issues.

Developed in parallel, new methods for providing this information to the market operator for incorporation into system control functionality will be required.

Milestone 5: By 2022, advanced protection mechanisms have been developed, trialled and validated to better address distributed energy resources impacts and enhance system operation and security.

An array of new advanced protection mechanisms will be required for areas of the grid where parameters such as frequency variations and voltage dips are more common. To allow this to happen seamlessly, integrated approaches will be required that will allow protection schemes to be incorporated into any new system architecture and future platforms.

These new advanced protection mechanisms will also require enhanced communications systems so island-enabling technologies can enhance system operation and security.

Key benefits

Security benefits

The transmission system's primary role is extended to ensure continued focus of system security and stability as key outcomes of a reengineered system. This ensures a robust and integrated approach for achieving security in the face of continued uncertainty over the diversity and nature of connection equipment.

Security benefits are achieved through avoiding the higher costs that would be necessary either to install additional and costly primary transmission capacity, or to impose more restrictive operational constraints to achieve the required levels of security. In circumstances where there are no direct cost implications there are operational savings that result because of the reduced risk and consequences arising from forced outages that impose financial costs and inconvenience on customers.

Market wide financial benefits

Market wide financial benefits are achieved through lower wholesale market prices that result from lower risk premiums or the avoided costs to provide physical capacity or equipment to mitigate these risks. Eventually these savings would be passed onto customers as bill savings.

Market performance benefits

Market performance benefits arise from the operational solutions that prevent generators and other market actors from exercising their market power. In the absence of the operational solutions there is the requirement for specialised alternative services that can only be physically provided by a small number of participants who could act to extract monopoly rents.

2017-27 Milestones and actions[13]

FOUNDATION						IMPLEMENTATION					
2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2027+

POWER SYSTEM SECURITY

Implement new frameworks and services for achieving system security with diverse generation and energy technologies and retain focus on physical and cyber security

Enhanced system operations at all voltage levels, as transmission networks offer additional services and distribution networks provide visibility of resources and other services

POWER SYSTEM SECURITY

Milestone 1

By 2018, the **central and transformed role for the transmission** system to support power system security has been defined

- Revise the regulatory test for transmission investment including interconnectors
- Develop new tools developed to assess, test and extend power system planning approaches
- Transmission businesses have commenced detailed evaluation and trials into the feasibility of employing additional sources of synthetic inertia such as electrical energy storage, SVCs and flywheels
- Develop transmission operating techniques for dealing with intermittent generation resources, including any changes required to market rules

Milestone 2

By 2018, **market based approaches for providing efficient capacity, and balancing and ancillary services** have been established, including a set of fully tested options that would cater for a very low emission generation mix

- Identify options to maintain system security in the event that a very low emission generation mix was to largely replace existing firm capacity plant
- Market based approaches for service delivery have been fully tested and evaluated
- Consider implementation of a market or alternative incentives based mechanism for achieving delivery of the service requirements

Milestone 3

By 2019, an initial approach has been developed for **coordinating and optimising decisions across the power system as a whole,** which includes more effective interfacing between the IMO and the distribution network connection points

- Specifications have been developed and agreed for scope and access to information at the interface between the transmission and distribution networks
- Capability for real-time communication and controls between the IMO and distribution system
- Enhanced intelligence & decision making tools at interface between transmission and distribution networks

13 Milestone timings are developed as a national guide for Roadmap Implementation. Timing of milestones and actions will differ across jurisdictions and different network areas. Milestone timings are specified as a latest end date, but many will require early action and may be completed earlier than outlined

FOUNDATION						IMPLEMENTATION					
2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2027+

POWER SYSTEM SECURITY

Implement new frameworks and services for achieving system security with diverse generation and energy technologies and retain focus on physical and cyber security

Enhanced system operations at all voltage levels, as transmission networks offer additional services and distribution networks provide visibility of resources and other services

POWER SYSTEM SECURITY

Milestone 4

By 2020, new tools and models have been developed to provide better **forecasting to better anticipate where environmental and system constraints could lead to system security issues**

- Development of new operational techniques for reliable forecasting of future operation of renewable generation and DER (2017–2018)
- Establish appropriate methodologies and processes for providing this information for the market operator control functionality (2017–2019)

Milestone 5

By 2022, **advanced protection mechanisms** have been developed, trialled and validated to better address DER impacts and enhance system operation and security

- Investigate and trial alternative protection mechanisms that exhibit better stability where frequency variations and voltage dips are more commonplace (2017–2019)
- Establish enhanced communications systems to enable island-enabling technologies, such as syncrophasor protection (2017–2022)
- Investigate the potential use of more integrated approaches that would allow protection schemes to be incorporated into new system architecture and platforms (2017–2022)

INTELLIGENT NETWORKS AND MARKETS

An expanding range of new energy technologies and services are supported while continuing to efficiently provide a range of traditional electricity services. Advanced network planning, operation and intelligence systems ensure the safe and efficient integration of large scale variable renewable generation, hundreds of micro-grids and millions of customer distributed energy resources. Market based mechanisms reward customers with distributed energy resources for providing network support services, orchestrated either directly or through other market actors.

10. GRID TRANSFORMATION

Background

Australia's future power system must transform to become a sophisticated and intelligent network that that will enable new and diverse technologies and services; increasingly dynamic markets and access to third parties; more active customer choice and control; and, new business models.

This transformation will need to be undertaken in a way that continues to ensure overall system resilience and stability is maintained, while providing overall cost reductions. A whole of system approach is required to a new power system architecture which ensures effective and secure integration across the entire electricity value chain. This approach is also needed to facilitate the connection of a diverse range of new technologies and equipment, while maintaining the performance and quality of the system. This will ultimately achieve significant operational benefits through optimisation and coordination of all connected devices with the network.

This power system architecture is the underlying structure of the electricity system, and the manner in which its components and its participants are organised and interact.

Drivers of change

- **Key driver 1:** Falling costs of large and small scale renewables and other distributed energy resources, such as rooftop solar, energy storage and electric vehicles, are driving rapid deployment and are encouraging both power system interdependence and independence. The change in mix of electricity generation requires new methods for managing system security (i.e. frequency, stability) as discussed in Section 9. In addition, the dynamic behaviour of the distribution system provides new challenges for effective transmission planning and operation. It requires a reassessment of the traditional basis for planning, requiring more sophisticated short and long term forecasting and active management of network, generation, demand and other services as variable renewable sources and distributed generation grow to make up a much larger share of total generation.
- **Key driver 2:** Evolving customer requirements are transforming power system dynamics in two ways. Firstly, customer choices are more directly driving investment trends by increasingly valuing services that use energy (e.g., heating, cooling, pool pumps, etc.). Secondly, technology innovations are enabling active customer participation, a step change in how customers participate in meeting their energy supply and demand requirements through distributed resources (i.e. solar panels, electric vehicles, home energy automation and storage). This occurs in response to the economic incentives provided by more efficient retail pricing (underpinned by more efficient network tariffs) implemented with smart meters.
- **Key driver 3:** The operation of the distribution networks will become much more dynamic and unpredictable with the connection of numerous new devices at the lowest voltage levels. This will potentially contribute significant new technical challenges to the performance and quality of electricity supply at the local level, but will also impact higher voltage levels. However, the dynamic characteristics and potential for disaggregated control of many of these new devices can also provide the mechanism for their effective integration into the distribution networks, which could be enabled through customer incentives. As the sophistication of monitoring and control devices continues to develop, these devices can be used to achieve a fully optimised level of control.
- **Key driver 4:** The requirement to provide access to electricity market ecosystems for customers and new market actors is increasing and diversifying. This trend is taking the shape of greater direct customer electricity market participation, including both generation and demand response. The emergence of new participants such as aggregators will require new transparent and simpler methods of interaction with the power system to enable this to be achieved at scale while mitigating any risks of disruption. Retailers and other market actors will be looking to the grid to support new services for and on behalf of customers. The key challenge will be in developing distribution network operating approaches that can deliver optimal outcomes, while dealing with the tension of managing market responses as part of achieving the required robust system operation from a technical perspective.

- **Key driver 5:** Power system resilience continues to be critical, however, instead of reinforcing existing systems by traditional means of grid strengthening, resilience planning considers mechanisms using the increased flexibility provided by the diversity of disaggregated control options and sophisticated network monitoring to respond to system constraints using lower cost operational measures.

Resilient 2027 Future State

- By 2027, the power system supports an expanding range of new energy solutions sought by customers and delivered by numerous market actors, while meeting expectations for reliability, cost and customer experience
- Advanced network planning and operation improve the operation of an integrated grid, including millions of distributed energy resources customers, which interoperate effectively
- Micro-grids and distributed energy resources provide credible non-network alternatives, which where required, can deliver equivalent firmness as would otherwise be provided by network replacement and augmentation, but at a lower cost
- The new technological capabilities developed, trialled and validated in the Australian context enable progressive implementation of advanced network optimisation through integrated and coordinated operation of the system at all levels to achieve the distribution system balancing now required

Key findings

EA Technology were commissioned to determine the features and characteristics of the future grid side architecture and systems required to unlock the maximum value from the large number of distributed energy resources that are connected to the network and form an integral part of the future power system.

Using CSIRO's 2050 Future Grid Forum scenarios, EA Technology:

- Identified the key actors in the future energy market
- Considered a number of use cases to identify the required functions of the future grid, evaluating the use cases against scenarios of technology uptake
- Applied the Smart Grid Architecture Model (SGAM) framework – which describes the various layers of the grid
- Identified key actions to achieve the features required

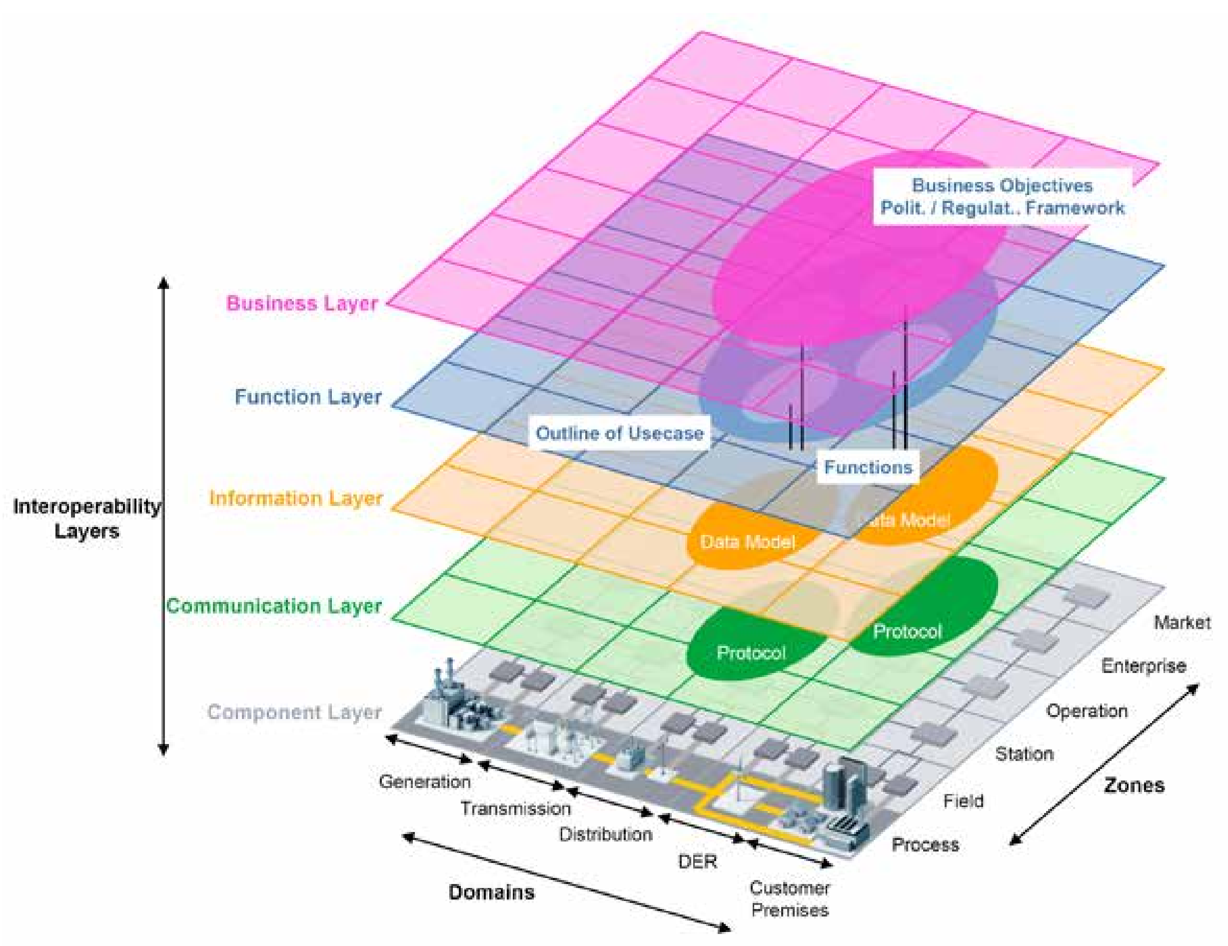
Finding 1: Networks provide benefits

The debate regarding the potential risk of customer defection from networks, due to the opportunity for them to supply their own power and save costs, has increased in recent times. However, detailed analysis indicates that this is only likely to provide economic benefits to a small proportion of customers. The traditional value created by networks from the efficient sharing of resources and extracting the value of diversity is available to be harnessed if customers stay connected. In fact, this value is likely to dramatically increase with the significantly increased range, diversity and distributed nature of new distributed energy resources that is connecting to the system.

Nevertheless, in the short term, the driver for maintaining a network connection goes beyond the opportunity that would be lost as a result of individual customers deciding to disconnect from the grid. Analysis shows that the required size of both solar PV cells and batteries to ensure the high levels of reliability demanded by customers would generally preclude standalone operation[14] without a significant change in customer expectations of their power supply, or the inclusion of an active generation source (e.g. a diesel generator) that could operate to relieve the shortfall.

14 This is based not only on the excessive costs that would be involved in providing the necessary capacity, but the physical limitations on roof space and within buildings for batteries. This is further exacerbated by the need to site a diesel generator in an environmentally acceptable manner.

Figure 23: Smart Grid Architecture Model (SGAM)



The analysis also indicates that by disconnecting from the grid the customer would lose the substantial benefits possible from the connection of their distributed energy resources to the network through energy service trading, back up, balancing and other services. This does not imply that the structure, design and role of networks will not be required to change to retain this benefit. For example, the development of mini-grids may be an economic alternative in many circumstances that provides the essential network benefits across a smaller number of connected participants, while meeting their needs for choice, control and competitive pricing.

Finding 2: Grid design and operation

The analysis identified that significant changes are required to current design and operational practices for the whole electricity system because of changes to both the type and location of new generation sources. The impacts of these changes at the transmission level are profound, and were explored in detail in Section 9 which discussed transformational requirements of the grid to maintain system security.

However, the analysis also identified that the operation of the distribution networks will also significantly change through the continued expansion of distributed energy resources. This expansion is changing the original distribution system design from unidirectional power flows to two-way power flows. In addition, there is the potential for these flows to fluctuate significantly within relatively short time periods.

This change has the potential to introduce a range of new technical challenges (i.e. voltage control). For example, typically there is a significant voltage drop that occurs over the length of any given feeder to its end point during the very heavy loads that occur during the evening peak. However, in the middle of a day with extreme solar radiation and a feeder with high PV penetration, there may be an inflow from this solar generation that would result in a significant voltage rise at the end of the feeder.

With unidirectional flow, there was limited need for control of the feeder as it was typically set up so that the range of anticipated voltage excursions did not exceed the allowable voltage limits. However, with increased distributed energy resources penetration, this is no longer possible in many cases without dramatic excursions outside the allowed voltage limits, unless dynamic control is implemented.

Given the relatively low level of monitoring and control that was implemented to cope with what was a relatively predictable operating regime, significant enhancement of monitoring and control functionality is required to provide for the robust connection of these devices within the technical envelope of the networks' capacity, and for the additional scope of optimising the performance of the integrated network with its connected devices.

It should be noted that without the grid development actions outlined in *the Roadmap*, these technical challenges identified above will limit the hosting capacity of networks. If unaddressed, the connection of the forecast increased levels of distributed energy resources would be inhibited or would see operational issues that could severely compromise electricity supply reliability, security and quality. As such the actions outlined in *the Roadmap* represent the required activities to develop the intelligent network capability to enable the anticipated future levels of distributed energy resources, and that the benefits of lower prices and carbon abatement that they will deliver.

Finding 3: The potential for optimisation

The diversity and number of new sources of load and generation at the edge of the distribution network has the potential to disrupt the traditional operating model. However, new innovations in real time monitoring and control at lower voltage levels, aided by the characteristics of the new devices being connected to the grid, have the potential for meeting the challenges through judicious utilisation of these connected devices, in an integrated manner with the network. Significant efficiency gains can be made by optimising operations and auxiliary systems using more sophisticated control systems and energy-efficient equipment.

This utilisation of connected devices will enable higher levels of distributed energy resources connection without compromising technical operation. It also provides the opportunity to optimise the operation of the distributed energy resources to maximise benefits to network operation without needing to augment the traditional capital intensive poles and wires that would otherwise be required to support peak levels on critically loaded infrastructure.

Finding 4: Forecasting energy and demand

Accurately forecasting energy and demand is becoming increasingly important and much more complex with increasing levels of distributed energy resources. Accurate forecasting is also required on a broader scale than previously. It must focus on:

» **Different time scales:** Accurate forecasts are required to ensure that future planning is efficient and not based on wildly inaccurate views of the future requirements. These should also be real time to facilitate the accurate matching of supply and demand required for reliable and secure system operation. These forecasts are impacted by a high level of uncertainty that results from volatility in weather, impacting on both solar and wind generation, as well as demand, making efficient planning of the network a significant challenge.

- **Different levels of the network:** Forecasting at transmission connection points is made dynamic by the concentration and volatility of distributed energy resources. The impact and approach for dealing with this has been discussed in Section 9. In addition, however, forecasting becomes a key problem at lower voltage levels, due to it being subject to significant stochastic variation which needs to be accommodated by secure operating practices. Load forecasting at the lower voltage levels requires a range of new techniques that includes an understanding of the different behavioural responses, as well as knowledge of the actual equipment installed, including at the detailed appliance level.

This increased extent of load forecasting requirements dictates that a more rigorous and holistic approach be developed to establish a coherent basis for load forecasting at all levels for long and short term planning, including operations.

Finding 5: Increased data transparency for customer participation and planning

Any new system that will enable wider customer participation in the power system and energy markets necessitates dissemination of a broader range of data. However, how this is undertaken will need to be carefully balanced by other key aims including privacy issues, data security concerns and achieving the delicate balance between openness and ensuring the efficient development of competitive markets. Access to data is therefore necessary to ensure fair access for all parties to the data that is required for them to operate. The extent and purpose of this data will need to be defined, and is a priority for early consideration in *the Roadmap* to allow customers to utilise network related data for their planning considerations.

Finding 6: Advanced power system architecture.

The analysis concludes that there is a need to redefine the structure and architecture of the electricity system to meet the requirement for flexibility and agility in the future grid.

This will require:

- **Greater network visibility:** Monitoring will be required to support the use of active system management, including forecasting of the future trends to optimise the overall development of the power system including network assets; demand, generation and other dispatchable energy resources; and, auxiliary services. Greater visibility of network data and of customer behaviour are essential in forecasting the developing trends and informing the necessary timing for further action.
- **Communications and data systems:** In order to enable the grid of the future to operate efficiently with real time transactions and control, the level of communication and data exchange will be far greater than it is today. This increase will be both in terms of the number of actors that need to be able to trade with each other, and the amount of data and information that they each require. At present the distribution system has reasonable communications links at the zone substation level (through its SCADA – substation control - infrastructure) to the outgoing circuit breakers on the medium voltage (MV) feeder network. However, communications at distribution substation and on the low voltage (LV) network are generally minimal. Lower voltage distribution networks will require greatest attention given the many connected devices and the need to enable voltage, power flow management and system balancing at a local level. Data protocols are developed that will ensure the appropriate data is captured, formatted, and securely held (particularly in the case of customer data).
- **Cyber security of systems:** Cyber security strategies will be essential to mitigate risks of damage and unauthorised use, or, exploitation of information and data, to ensure confidentiality, integrity, and availability.
- **Decentralised control:** The need for a distributed control architecture to make decisions and take actions at a local level will be required.

Finding 7: Implications for the Australian power system

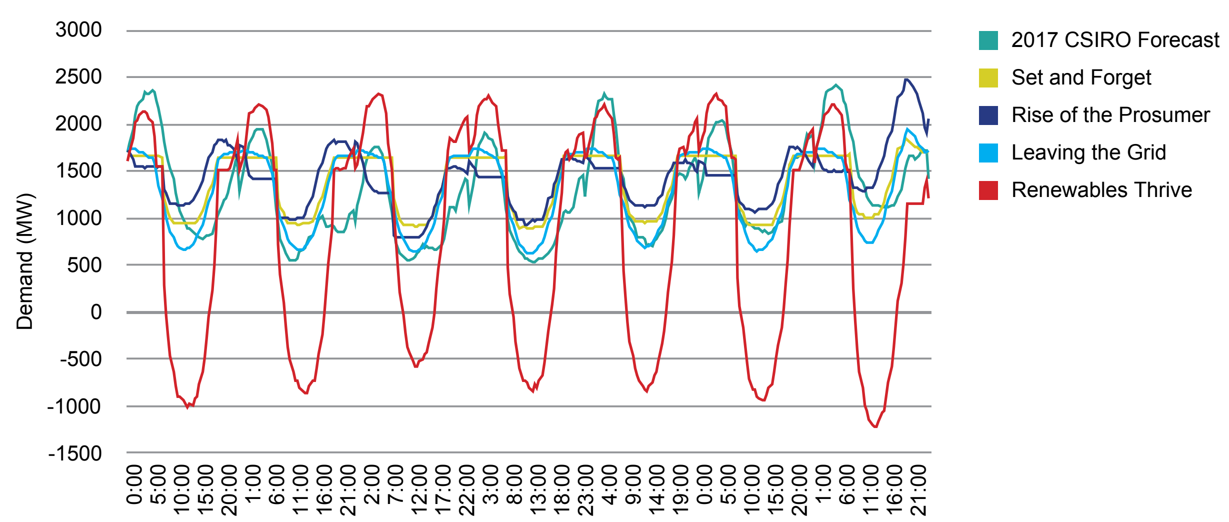
The high-level impacts of the different mix in electricity generation were examined by looking at a period during both summer and winter in 2027 and comparing that with the base case demand levels anticipated in 2017 (Figure 24). This analysis allowed for the connected distributed generation, the anticipated levels of demand response and use of storage and electric vehicles.

» This analysis established that there are differences between jurisdictions in the NEM in relation to the challenges that they will face. For most jurisdictions, there is an expectation of a reduction in peak demand and a narrowing of the band between maximum and minimum loading conditions. In theory, this should not pose excessive challenges in terms of balancing and frequency control.

» However, for some jurisdictions, the outlook is more challenging. For instance, South Australia's demand in 2027 under the four CSIRO Future Grid Forum scenarios is identified in Figure 24.

Here it can be observed that the peak demand remains fairly consistent (increasing slightly) but the minimum demand reduces substantially. This will pose material challenges as the rate of change from South Australia consuming power to exporting power is rapid over the course of a day and managing these swings on the network will require close attention.

Figure 24: South Australia summer demand in 2017 and 2027 (based on data from CSIRO)



Analysis was undertaken to quantify the scale of difference between the anticipated demands in 2017 and 2027 across the NEM. Figure 25 indicates that under a high penetration renewables scenario (CSIRO's Future Grid Forum Renewables Thrive scenario), there would be a greater level of demand erosion, with all jurisdictions seeing material reductions. South Australia remains the only jurisdiction which is becoming a net exporter of power by 2027 on these sample days of the scenario and this chart illustrates the significant levels of change in the demand profile from those experienced today.

This analysis highlights the importance of advanced network planning and forecasting of renewables within each NEM region.

Finding 8: Critical gaps in innovation.

A number of key priorities and opportunities for innovation have been identified where gaps currently exist in regard to the Australian power system. These include:

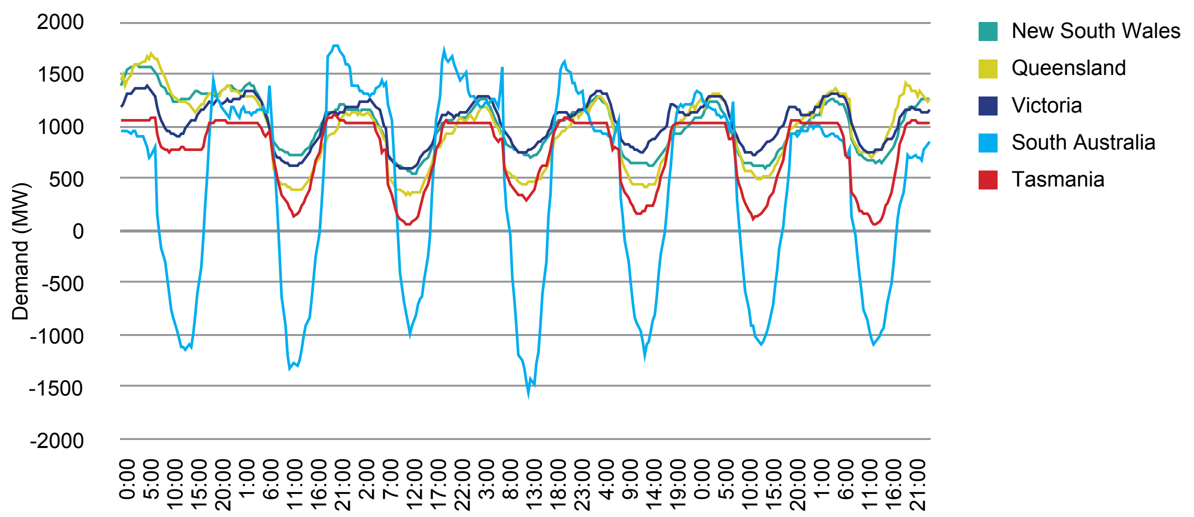
» Voltage management on medium and low voltage networks

» Frequency control in an environment with a mix of large scheduled, distributed and/or variable generation and for either interconnected or islanded operating modes

» Use of decentralised control techniques to allow greater opportunity for local control and decision making in distribution networks

» Addressing local distribution network constraints and power flow issues through more active and dynamic network management

Figure 25: Expected demand by state in 2027 under the Renewables Thrive scenario (data from CSIRO)



» Optimising the operation of demand side response to achieve the aims of system balancing and constraint management, while ensuring that network performance is not compromised when demand side response is used for other purposes

Innovation in these areas will address some of the key challenges identified throughout the Network Transformation Roadmap. These activities need to commence in the immediate term such that the learning can be encapsulated in business as usual in advance of the innovations being required on a day-to-day basis and to avoid network responses being overtaken by the pace of change.

Reference documents

Documents that provide additional background to these findings include:

» The embedded generation project: Final Report. Marchment Hill Consulting & CSIRO for ENA (2015)

» Electricity Network Transformation Roadmap: Grid design, operation, platform & telecoms report, EA Technology, (2016)

» Electricity Network Transformation Roadmap: Innovation gap analysis and plan, EA Technology, (2016)

2017-27 Milestones

The Roadmap outlines a series of milestones which provide markers of progress over the decade toward the *Resilient 2027 Future State*. Each of the milestones are supported by a series of integrated actions.

Milestone 1: By 2018, the approaches and protocols to address the management and exchange of information between networks and distributed energy resources participants and allow effective coordination of the system in real time and supports full interoperability are determined. These approaches would be established with the highest levels of security including data management, information privacy and cyber security.

A range of new approaches to information management, access and exchange are essential if system interoperability and coordination of the system in real time are to be made possible. The development of principles and rules embedded in the governance processes for all stakeholders implementing software solutions and communications systems are also critical in facilitating new platforms and markets across the sector.

To support these approaches, minimum technical requirements are required through the development of open standards and protocols, aligned to international standards where possible, for areas such as information, data and communication systems or electric vehicle integration that also ensure the highest levels of security are maintained.

Milestone 2: By 2019, an integrated suite of advanced network planning models, techniques and distributed energy resources services valuation methods have been established as foundational to the mainstreaming of distributed energy resources services as non-network alternatives.

A range of new network forecasting, planning and valuation tools and hosting capacity analytics will be foundational to distributed energy resources services becoming mainstream alternatives to traditional network augmentation and replacement.

Developed initially as a range of standalone tools or techniques, capabilities will be required for enhanced network topology mapping and distributed energy resources hosting capacity, distributed energy resources locational value analysis and distributed demand/supply forecasting.

Milestone 3: By 2019, an integrated suite of distributed grid intelligence and control architectures and tools have been agreed as foundational to the safe, reliable and efficient operation of a high distributed energy resources distribution system.

To ensure the safe, reliable and efficient operation of a high distributed energy resources distribution system, significant enhancement of monitoring and control architectures and functionality are required. An accelerated penetration of smart meters, identified as essential for delivering better outcomes to customers through pricing and incentive reform, will also contribute to the development of a platform for grid intelligence and control.

Enhanced grid intelligence will assist with the identification and management of system constraints that could threaten operability of the system from any location, and will enable the power system to respond readily to change.

These tools and architecture will also provide the additional scope of optimising the performance of the integrated network with its connected devices.

Milestone 4: By 2020, an integrated suite of advanced network operation mechanisms and tools have been agreed as foundational to the safe, reliable and efficient operation of a high distributed energy resources distribution system which also contributes to overall power system security.

Network operation mechanisms have been enhanced to provide real time identification and communication of network support requirements at both the locational and temporal levels.

With the increase in the dynamic behaviour of the distribution system, enhanced visibility, communication and coordination between the independent market operator (IMO) and network or distribution system operator will be required to assist in the system wide active management of network, generation, demand and other services as utility and rooftop scale variable renewable generation grows to make up a much larger share of total generation.

Milestone 5: By 2022, the full suite of Advanced Network Optimisation (ANO) tools have been trialled and validated across a diversity of Australian network topologies and DER "scenarios".

Once developed, a variety of new and advanced network planning tools, advanced distributed grid intelligence and control systems and advanced network operation systems will need to be tested and validated against all potential operating situations to ensure that they are fit for purpose and can be rolled out as required by networks.

Initially networks with very high distributed energy resources levels are likely to provide the network investment required to test these solutions, focusing on areas where there is a convergence of demand growth and high levels of existing or emerging distributed energy resources.

Milestone 6: By 2022, undertake R&D activities to identify solutions for identified technological gaps in the current Australian power system.

A number of key technical challenges and/or gaps in innovation have been identified which need to be addressed if grid transformation and optimisation is to be achieved. Key areas where gaps were identified include, voltage management, frequency control, decentralised control techniques, management of local constraints and optimising demand side services.

Therefore, business investment in research and development is required that will find solutions and enable new technologies to be developed, tested and integrated into the system whilst improving grid resilience at both a local and system wide scale.

Key benefits

The benefits associated with the transformation of Australia's power system include:

Direct participation by customers

The customer of the future will be better informed, modifying the way they use and purchase electricity. They have choices, incentives, and disincentives. Customers will have the choice of options in the way they use and pay for energy. Active customers may be able to balance their energy consumption with the real-time supply of energy and new information infrastructure will support additional services not available today. Other customers will choose to purchase services in which retailers or other market actors manage the volatility of prices for grid and wholesale prices on their customers' behalf. This capability will also allow new actors to develop which may offer services of an aggregated nature.

Accommodating all generation and storage options

By transforming and optimising how Australia's power system is integrated and functions, it will unlock the full value of all generation (including distributed energy resources) and storage options at both the grid and household scale, and may include system aggregators with an array of generation systems.

Enabling new products, services, and markets

Grid transformation will enable market systems that provide cost benefit trade-offs to third party participants and customers by creating opportunities to bid for competing services.

Providing power quality and reliability

The transformed grid provides a reliable electricity supply with fewer and briefer outages, cleaner power, and self-healing systems, through the use of digital information, automated control, and autonomous systems, with distributed generation sources changing the traditional network reliability paradigms.

Optimised asset utilisation and provides operational efficiency

Network assets will operate and integrate well with other assets to maximise the end to end operational efficiency and reduce costs.

Anticipating and respond to system disturbances

The transformed grid will be better placed to independently identify and respond to system disturbances and undertake mitigation efforts to correct them. Network operators will use predictive analysis to identify issues; initiate corrective actions; react quickly to electricity losses; and, optimise restoration times and costs.

Operating resiliently and managing environmental impacts

The future grid will have the ability to resist attacks on both the physical infrastructure (substations, poles, transformers, etc.) and the cyber structure (markets, systems, software, communications). Sensors, cameras, automated switches, and intelligence are built into the infrastructure to observe, react, and alert when threats are recognised within the system.

2017-27 Milestones and actions[15]

FOUNDATION						IMPLEMENTATION					
2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2027+

INTELLIGENT NETWORKS & MARKETS

Develop essential information tools for a cost effective Integrated Grid, including: open standards, extended monitoring, advanced planning and feeder hosting analysis, and the mapping and locational valuation of distributed energy resources

Establish active distribution system operations and markets for technical stability and optimising investment by procuring distributed energy resource based grid support. Evaluate cost benefit analysis of procuring these services through a digital market platform

GRID TRANSFORMATION

Milestone 1

By 2018, **establish approach & protocols to address the management and exchange of information** between networks and DER participants to allow real-time system operation & interoperability

- Establish agreement across all industry stakeholders regarding the form and arrangements for access to data and systems
- Develop principles for all projects implementing software & communications systems
- Establish minimum technical requirements for information, data and communication architecture
- Establish minimum technical requirements for cyber security, data privacy and warehousing
- Ensure that there are robust testing procedures to be followed in system implementation, auditing & reporting

Milestone 2

By 2019, an **integrated suite of advanced network planning models, techniques and DER-services valuation methods** have been established as foundational to the mainstreaming of DER-services as non-network alternatives

- Develop tools for evaluation of cost-benefits of the range of technological and commercial solutions that will be deployed
- Develop and run new DER adoption forecasting tools
- Develop and run new dynamic distribution system demand/supply load forecasting models for grid impacts from load/DER growth
- Decide on utility's overall DER strategy and any related changes to the business model to support effective DER integration

Milestone 3

By 2019, an **integrated suite of distributed grid intelligence and control architectures and tools** have been agreed as foundational to the safe, reliable and efficient operation of a High-DER distribution system

- Identify the technical priorities for distributed grid intelligence and control
- Develop a framework to facilitate Demand Side Response and appropriate monitoring
- Establish minimum technical standards for LV system sensing & measurement
- Minimum technical requirements established for DER & microgrid interoperability

15 Milestone timings are developed as a national guide for Roadmap Implementation. Timing of milestones and actions will differ across jurisdictions and different network areas. Milestone timings are specified as a latest end date, but many will require early action and may be completed earlier than outlined

	FOUNDATION						IMPLEMENTATION					
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2027+

INTELLIGENT NETWORKS & MARKETS

Develop essential information tools for a cost effective Integrated Grid, including: open standards, extended monitoring, advanced planning and feeder hosting analysis, and the mapping and locational valuation of distributed energy resources

Establish active distribution system operations and markets for technical stability and optimising investment by procuring distributed energy resource based grid support. Evaluate cost benefit analysis of procuring these services through a digital market platform

GRID TRANSFORMATION

Milestone 4

By 2020, an integrated suite of **advanced network operation mechanisms and tools** have been agreed as foundational to the safe, reliable and efficient operation of a high DER distribution system which also contributes to overall power system security

- Minimum technical requirements for real-time identification and communication of network support requirements
- Minimum technical and procedural requirements have been established for enhanced visibility, communication and co-ordination between the IMO and DNSP/DSO

Milestone 5

By 2022, the full suite of **Advanced Network Optimisation (ANO) tools** have been trialled and validated across a diversity of Australian network topologies and DER scenarios

- Advanced network planning tools have been developed, trialled and validated
- Advanced distributed grid intelligence and control systems have been developed, trialled and validated
- Advanced network operation systems and procedures have been developed, trialled and validated

Milestone 6

By 2022, undertake **R&D activities to identify solutions** for identified technological gaps in the current Australian power system

- By 2018, an R&D program and framework has been established to begin to address current gaps in innovation
- By 2020, solutions for current gaps identified, and are being tested and validated in a network environment
- By 2022, solutions that have been found viable have been commercialised and deployed as required

11. NETWORK OPTIMISATION AND PLATFORMS

Background

In Australia's increasingly decentralised energy future, millions of distributed energy resources customers will be able to provide network support services. This could occur through direct relationships with networks (as has long occurred in load control programs) or through other market actors who manage distributed energy resources fleets on behalf of customers.

When properly integrated, distributed energy resources can provide a cost-effective alternative to capital intensive network investments in specific locations. More advanced approaches to integrating distributed energy resources will also enable the provision of real time services that maximise the operational efficiency of the network and may involve:

- improving voltage control;
- constraint management for lower voltage networks; and,
- assisting in more coordinated control of the interface between the transmission and distribution networks.

In other words, well integrated distributed energy resources can provide valuable services to electricity networks and other market actors. This provides an opportunity for customers to maximise the return on their distributed energy resources investment while also helping reduce network expenditure. Where implemented as a whole-of-system set of solutions, this can support positive bill outcomes for all customers, whether or not they have distributed energy resources.

A number of new market actors are currently seeking to provide customers with distributed energy resources solutions that provide financial benefits from maximising self-consumption and wholesale market participation. Given the relatively recent advent of large numbers of distributed energy resources however, and the need to ensure network support services provided are robust and reliable enough to offset capital expenditure, systems for procuring distributed energy resources network services are still in their infancy globally.

Drivers of change

The electricity system was not originally designed to accommodate millions of distributed energy resources. Not surprisingly, the very significant growth in distributed energy resources adoption by customers has resulted in many well documented technological impacts that must be managed to maintain power quality and network security. This results in economic costs that are borne by all electricity system customers whether they own distributed energy resources or not.

Given the scale of distributed energy resources adoption by Australians, the vast majority of whom continue to be connected to the electricity network, there is an opportunity to transition to a future where distributed energy resources are a key part of a more efficient, reliable electricity system.

Figure 26: Unlocking the full value stack of distributed energy resources services can be difficult

SOURCE OF VALUE	TYPE AND ACCESSIBILTY OF VALUE	
Wholesale market	Financial	✓✓✓✓✓
Transmission networks	Financial	✓?
Distribution networks	Financial	✓?
Customer self-consumption	Financial	✓✓✓✓✓

The key motivation for examining distributed energy resources market operation and orchestration, therefore, is to establish the best ways for customers to maximise the return on their distributed energy resources investments in a way that provides the desired individual benefits, while also selling services that help optimise the operation of the system to benefit all members of society.

Applying an integrated and market based approach to how electricity networks and distributed energy resources function effectively together can provide a range of benefits. For example, it:

» increases the range of customer options for how customers may choose to operate their distributed energy resources, allowing them to achieve value in alternative markets;

» helps reduce, defer or eliminate the need for expensive network replacement and augmentation, resulting in a cost saving for customers through reduced network charges; and,

» provides new options for more secure real time operation of the network by providing a dynamic control capability that can be employed under a range of conditions to ensure the integrity of the system operation.

The transition to a lower carbon decentralised yet integrated operating model, where the traditional electricity system seamlessly interoperates with millions of distributed energy resources, is still in its infancy. Given the scale of customer benefits that are expected to accrue, and the fact that very large volumes of distributed energy resources are and will continue to be privately owned, market based solutions are expected to be essential for motivating and rewarding participation.

Under such a market based model, it is expected that procurement of distributed energy resources services will initially be through very basic Network Optimisation Market (NOM) processes, either directly with customers and/or through market actors. These processes will mature over the decade and sophisticated digital platforms - digital Network Optimisation Markets (dNOM) - are likely to be evaluated late in the decade to procure and automate real time network optimisation services and perhaps support a range of other energy innovations.

Resilient 2027 Future State

» By 2027, millions of privately owned distributed energy resources are achieving benefits for their owners and reducing overall costs by providing services that help optimise Australia's electricity system (either directly or through their agents)

» In this increasingly high distributed energy resources future, Advanced Network Optimisation (ANO) technological functions at the distribution level support the stable operation of Australia's low, medium and high voltage systems

» In parallel, Network Optimisation Markets (NOM) provide a technology neutral mechanism for procuring distributed energy resources network optimisation services where and when needed

» By 2027, customer savings and economic benefits are being achieved through orchestration of distributed energy resources procured on a dynamic, locational basis.

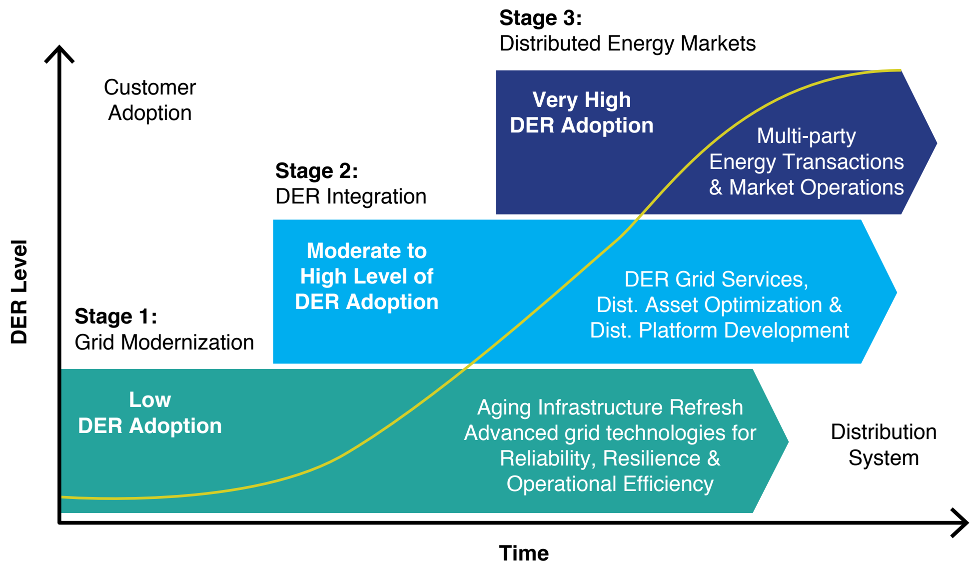
Key findings

Substantial work has been carried out globally to investigate the status of network transformation and optimisation in the context of low carbon electricity systems that have growing levels of distributed energy resources penetration.

For developed nations with established electricity systems, it is widely recognised that electricity network transformation will require a series of progressive and purposeful stages, such as in De Martini's Three stages of distribution system transformation diagram (Figure 27).

While the later transformational steps involving mature system operational innovations and trading platforms remain in their early stages of development, there are significant learnings from both Australian and international expertise that have informed *the Roadmap*. Following are several key findings that are particularly relevant to Australia's highly decentralised energy transformation.

Figure 27: Three stages of distribution transformation (De Martini)



Finding 1: Integrating high levels of variable renewable energy and distributed energy resources markedly increases the complexity of network management and requires the holistic application of advanced technologies and tools to ensure stable and efficient operation.

The majority of Australians will continue to depend on the benefits provided by electricity transmission and distribution networks as they evolve to support a much wider range of energy sources. These core benefits include:

- sharing of energy resources, which provides customer value through network effects and economies of scale; and,
- enabling the natural diversity of millions of connected customer loads and generation to help instantaneously match supply and demand.

An increasing dependence on variable renewable energy sources and millions of distributed energy resources markedly increases the complexity of managing an electricity network. This requires the development of a new range of advanced planning, distributed intelligence and operational tools (Section 10). It also requires the holistic and systemic application of those tools to efficiently manage multidirectional electricity flows across the network while maintaining system stability.

The Roadmap distinguishes the systemic application of advanced new tools for this purpose as Advanced Network Optimisation (ANO). This avoids the lack of clarity that can arise by using the term Distribution System Operator (DSO) as it is defined in many ways in the international literature. *The Roadmap* recognises that ANO technological functions will be increasingly necessary to ensure efficient management of Australian electricity networks that have high levels of variable renewable energy and distributed energy resources. It also recognises that many ANO functions may naturally arise as an extension of current utility functions.

Finding 2: The orchestration of distributed energy resources can provide valuable services that help optimise electricity network operation and provide customers with opportunities to participate in response to financial incentives.

Where well integrated, aggregated distributed energy resources can provide a cost-effective alternative to capital intensive network investments in specific locations. More advanced approaches to integrating distributed energy resources will also enable real time services to be provided that maximise the operational efficiency of the network.

Effective network and distributed energy resources co-optimisation involves customers allowing their privately owned distributed energy resources to provide an agreed service to the electricity network. This will generally be in the form of energy (or reactive power) at a time when the service can help reduce the costs or operational complexity of network operation. In most cases this will be automated either directly or through the customers' agent.

Methods for enabling network and distributed energy resources co-optimisation may include either the mandating of direct distributed energy resources control (perhaps as a condition of connection) or the network actively procuring it via market mechanisms. The market arrangements will initially be simple, perhaps involving a bilateral contract allowing manual control, or voluntary participant response. Arrangements may be between customers and networks directly and/or involving market actors specialising in distributed energy resources fleet management.

Where electricity networks are transformed to enable the orchestration of distributed energy resources, grid connected customers are likely to achieve the maximum benefits from their distributed energy resources investment by providing such services in return for the financial incentive.

Finding 3: The selection and implementation of market design features is critical to ensure that customers, networks and society benefit from distributed energy resources orchestration.

The optimisation and orchestration of a decentralised and integrated electricity system involving millions of distributed energy resources will not just happen. Certain basic architectural principles should be implemented to create a NOM. For example, such a system must be[16]:

» **Coordinated and self-optimising:** The system must seamlessly enable distributed energy resources fleet 'orchestration' and self-optimisation at the customer level

» **Technical and economic benefits:** The system must enable the integration of distributed energy resources in a way that supports both power system reliability and economic efficiency

» **Firmness of response:** The system must be designed to ensure firmness of response from distributed energy resources at all critical times (with equivalent certainty to traditional network replacement and augmentation where it is relied on to reduce or avoid that expenditure)

» **Non-discriminatory:** The system must provide for non-discriminatory participation by qualified participants

» **Transparent:** The system must ensure the value of network optimisation opportunities is transparent and the benefits are received for actual distributed energy resources services provided

16 Modified with permission from Transactive principles outlined in *Decision-Maker's Transactive Energy Checklist*, The GridWise Architecture Council (August, 2016).

» **Verifiable:** The system must be observable and auditable at its interfaces

» **Future proof:** The system must be scalable, adaptable, and extensible across a number of devices, participants, and geographic extent

Finding 4: The form of the Network Optimisation Market (NOM) is expected to evolve from relatively simple procurement models over time, depending on the business case for moving from simple programs and contracts to more sophisticated arrangements.

Like other aspects of network service delivery, the procurement model should be justified by value created. There is value in retaining optionality as to the ultimate form of the Network Optimisation Market, including assessing whether the benefits of digital platforms outweigh the costs.

The conceptual benefits of co-optimised distributed energy resources and network functions have been investigated in several jurisdictions. However, there is only limited operating experience since there is significant lead time in developing the capability including the very significant amount of data that is required. Software algorithms and systems that utilise real time data are also essential ingredients of a fully operational approach to optimising the performance of networks and customer distributed energy resources. There is also a trade-off between transaction costs and benefits of increasingly complex arrangements which need to be assessed progressively in the light of experience.

At the same time, there are a range of essential functions that are extensions of the current distribution network responsibilities. These will provide the initial steps to unlock this value. Therefore, a staged approach is recommended, with successive development occurring when the benefits of the previous stage are identified and proven.

Finding 5: The progressive development and implementation of a Network Optimisation Market (NOM) is a no regrets action.

There is an intrinsic relationship between a potential future distribution level energy market and the development of the NOM. This is because the same distributed energy resources can provide services and be compensated in both markets.

While the ideal approach may be to develop consistent market arrangements for both purposes, this would require prejudging the future development of nascent energy markets and digital platforms. The development of NOM processes and structures represents a no regrets approach which avoids unnecessary delays but would not foreclose the future potential for alternative market structures where they are justified.

Reference documents

Documents that provide additional background to these findings include:

» Electricity Network Transformation Roadmap Grid design, operation, platforms & telecoms report, EA Technology, (2016)

» Distribution systems in a high DER future: Planning, market design, operation and oversight, Lawrence Berkeley National Laboratory, De Martini & Kristov (2015)

» Decision-Maker's transactive energy checklist, The GridWise Architecture Council (2016)

» Future market platforms and network optimisation - Synthesis Report. Drawn from international consultant reports (2017)

2017-27 Milestones

The Roadmap outlines a series of milestones which provide markers of progress over the decade toward the Resilient 2027 Future State. Each of the milestones are supported by a series of integrated actions.

Importantly, it should be noted that the following Milestones are directly related to and dependent upon activities outlined earlier in Section 10, *Grid transformation*.

Milestone 1: By 2018, networks with very high distributed energy resources levels are implementing basic NOM functions to procure locational distributed energy resources services for network support, either directly from customers and/or through their agents.

There is a significant amount of preparatory work to develop the optimisation methodology and support it as required with distributed monitoring and control devices. Early consideration will be given to identifying beneficial locations and providing transparent information to participants about how they may contribute distributed energy resources capacity.

This will enable the development of a fleet of customer owned distributed energy resources that are orchestrated initially in a limited manner to defer network investment. This development will provide experience and facilitate an increased understanding of the commercial expectations of participants and the value provided through the distributed energy resources provision.

Milestone 2: By 2019, a basic set of Advanced Network Optimisation (ANO) functions are performed where networks with very high distributed energy resources levels progressively implement advanced network planning tools, distributed grid intelligence and control and advanced network operation techniques.

This milestone introduces more sophisticated techniques for the utilisation of distributed energy resources. It is used as part of a coordinated and automated process for network management, for example, assisting in managing voltage excursions, responding to loading unbalance in real time or managing short term constraints, perhaps as part of an automated and intelligent control scheme to achieve integrated system operation.

This may involve initial trials using the fleet of distributed energy resources procured for the first milestone. Ultimately all new distributed energy resources would be procured with the expectation of being used with the more advanced functionality provided for this milestone.

Milestone 3: By 2020, collaborative projects demonstrating the integration of Advanced Network Optimisation (ANO) functions and NOM procurements have validated direct and market based orchestration of distributed energy resources as a reliable non-network alternative.

There is enough distributed energy resources volume and utilisation in use, together with sufficient trials of advanced market procurement, to provide a clear demonstration that it has achieved its objectives.

This milestone implies that a rigorous review be undertaken to analyse the experience to date and would include technical assessments of the system optimisation algorithms and implementation, achievements of benefits, achievement of value by participants, and change in risk profile.

Ultimately the approach will be considered successful if it has met the needs of networks and distributed energy resources providers while maintaining customer utility.

Milestone 4: By 2023, networks with very high distributed energy resources levels are performing an integrated set of Advanced Network Optimisation (ANO) functions and NOM procurements as mainstream activities to ensure technical stability, economic efficiency and market animation.

Based on the successful achievement of the preceding milestone, further measured development has occurred to embed ANO and NOM activities within mainstream network operations.

Based on benefit realisation over a sufficient period of time, this approach is considered to have been proven under all foreseeable circumstances as providing a technically stable and economically efficient means of integrating distributed energy resources into the network.

Milestone 5: By 2027, a feasibility study, cost benefit analysis and conceptual design of a digital Network Optimisation Market (dNOM) is complete.

Where there are clear economic benefits, there may be the potential to extend the scale of distributed energy resources participant involvement through the development of a digital Network Optimisation Market (dNOM). This could have the benefit of allowing smaller users to interact with a market for provision of their distributed energy resources. It could provide a more consistent and transparent basis for participation for all distributed energy resources providers.

However, it is also anticipated that there would be significant transaction costs. Additionally, there is the possibility towards the end of *the Roadmap* decade that consideration will have been given to the development of a distribution energy market, initiated by non-network stakeholders. Such considerations should be undertaken as these markets begin to emerge and mature.

These, and other factors will fundamentally impact on whether or not the development of a dNOM will provide sufficient additional benefits to justify the costs. Furthermore, the evidence to support such a cost benefit analysis requires the active development of distributed energy resources markets and procurement of orchestration services by networks in the NOM as per the previous milestones.

Key benefits

Delivering significant cost savings

The main value of the transformation of networks is achieved through the reduction and deferral of network replacement and augmentation costs, a large component of which is facilitated through the activities described in these milestones. This benefit is sufficiently crucial to require the inclusion of a specific milestone to demonstrate that the intended value of the transformation is delivered.

Providing additional choices for distributed energy resources owners

The other benefits achieved by this work package are secondary, but nevertheless contribute to the overall objectives of *the Roadmap*. The development of a NOM and potentially a dNOM allows additional customer choice by providing alternative markets and value streams that are available to distributed energy resources owners.

While it may be anticipated that the decision for a distributed energy resources owner to participate will be dictated largely through the incentives and the anticipated value, the provision of choice is a desirable objective of the transformation of the industry.

Establishes a clear strategy and plan for subsequent stages of the development of markets

The work package does not necessarily result in the final outcome for the network optimisation (NOM). It specifically includes a review process that will establish the ongoing vision for the best long term approach given the experience gained from the incremental based development process, and the environment that exists at the time. The completion of a rigorous business case will provide certainty regarding the future direction and avoid any development that cannot clearly be shown to be beneficial.

It could be expected that the development of platforms and the potential for additional services and roles to be developed in line with further industry change will be an ongoing process that may require periodic revision of the vision and further business case assessment.

2017-27 Milestones and actions[17]

FOUNDATION						IMPLEMENTATION					
2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2027+

INTELLIGENT NETWORKS & MARKETS

Develop essential information tools for a cost effective Integrated Grid, including: open standards, extended monitoring, advanced planning and feeder hosting analysis, and the mapping and locational valuation of distributed energy resources

Establish active distribution system operations and markets for technical stability and optimising investment by procuring distributed energy resource based grid support. Evaluate cost benefit analysis of procuring these services through a digital market platform

NETWORK OPTIMISATION & MARKETS

Milestone 1

By 2018, networks with very high DER levels are **implementing basic Network Optimisation Market (NOM) functions** to procure locational DER-services for network support, either directly from customers and/or through their agents

- Identify key locations where DER may result in short term savings in network augmentation
- Establish and collate information to allow participants to assess available opportunities for DER provision
- Establish simple procurement mechanisms that encourage participation from DER owners or aggregators
- Utilise DER with the initial and simple processes developed in Section 10 milestones
- Review the outcomes to confirm participant expectations are met and satisfactory achievement of benefits

Milestone 2

By 2019, a basic set of **Advanced Network Optimisation (ANO) functions are performed** where networks with very high DER levels progressively implement advanced network planning tools, distributed grid intelligence and control and advanced network operation techniques

- Develop advanced optimisation tools (Section 10) and establish the interfaces to ensure that it may operate effectively with DER on an automated basis
- Procure DER resources with the capability and expectation of being utilised with automatic optimisation processes, with appropriate incentives to motivate their participation
- Some utilities establish trials to test the technical operation of the optimisation processes to meet a range of system objectives

Milestone 3

By 2020, collaborative projects demonstrating the **integration of Advanced Network Optimisation (ANO) functions and NOM procurements** have validated direct and market based orchestration of distributed energy resources as a reliable non-network alternative

- Select a range of DER implementation examples that cover a broad range of operating conditions and characteristics
- Carry out a review in conjunction with AEMO to validate their technical performance for all potential operating modes
- Review the procurement processes to ensure that these are effective and that the incentives are appropriately attracting DER
- Outcomes from trials are shared among network owners to establish need for standardised approaches across the NEM

17 Milestone timings are developed as a national guide for Roadmap Implementation. Timing of milestones and actions will differ across jurisdictions and different network areas. Milestone timings are specified as a latest end date, but many will require early action and may be completed earlier than outlined

	FOUNDATION						IMPLEMENTATION					
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2027+

INTELLIGENT NETWORKS & MARKETS

Develop essential information tools for a cost effective Integrated Grid, including: open standards, extended monitoring, advanced planning and feeder hosting analysis, and the mapping and locational valuation of distributed energy resources

Establish active distribution system operations and markets for technical stability and optimising investment by procuring distributed energy resource based grid support. Evaluate cost benefit analysis of procuring these services through a digital market platform

NETWORK OPTIMISATION & MARKETS

Milestone 4
By 2023, networks with very high distributed energy resources levels are performing an **integrated set of Advanced Network Optimisation (ANO) functions and NOM procurements** as mainstream activities to ensure technical stability, economic efficiency and market animation

- Trials successful in multiple network areas, with different network structures, and technical resilience is demonstrated (2021–2023)
- Anticipated economic benefits and participant's general expectations from their involvement are being achieved (2022–2023)
- Trials progressively normalise interconnection and islanding of microgrids and virtual power plants, including effective treatment for unexpected events (2022–2023)
- Standards implemented for communication and interfaces that simplify participant involvement (2023)

Milestone 5
By 2027, a feasibility study, Cost/Benefit Analysis and **conceptual design of a digital Network Optimisation Market (dNOM) platform** is complete

- Establish the value being derived from the use of DER through current procurement methods and the potential for greater use (2025–2026)
- Collaborate with policy makers and regulators to investigate the possible parallel development of a customer energy market (2025–2026)
- Develop a high level functional dNOM specification sufficient to base a high-level estimate of the cost of implementing this approach (2026–2027)
- Finalise analysis including stress testing with overseas utilities who have investigated or implemented the approach (2026–2027)
- Make recommendations regarding the need and scope of a possible dNOM implementation (2027)

12. TECHNICAL ENABLERS

Overview

As described in the previous sections the transformation of power system security and grid transformation will have far reaching implications for the corporate capability of networks and other parties.

To enable this transition to take place, the key technical enablers needed to underpin its development must be addressed. This section will examine key technical enablers including:

» Technical standards and regulations

» Future workforce requirements

Electricity standardisation ensures consistency in accepted practices. These practices are essential for quality assurance, energy efficiency, design, grid reliability, infrastructure compatibility, utility interoperability and overall effectiveness. However, the most critical role standards and workforce training provides is ensuring the safety and wellbeing of both the public and all network employees and other professionals who interact or provide services to the power system.

Technical standards and regulations

Background

The generation, distribution, and consumption of electricity is currently undergoing extensive change. Developments in electrical storage, new types of generation, the emergence of the 'Internet of Things', consumer preferences, and other drivers are encouraging innovation and adaptation of existing infrastructure to support new demands and directions.

In the energy and electro-technical sectors, standards have been identified as playing a key role in enabling more transactive power systems by supporting interoperability between technologies, providing consistent frameworks for design and implementation, and ensuring safety.

Drivers of change

- **Key driver 1:** The scale and complexity of the electrical grid and its transformation necessitate that those involved in developing and managing it share a common understanding of its operational details.
- **Key driver 2**: Integration and interoperability are fundamental to the performance of the power system of the future, which will be managed and coordinated by communications and control systems. These systems will need to be designed to be integrated into effective cooperation and two-way communication among the many interconnected elements of the power grid.

Resilient 2027 Future State

- By 2027, a strategically aligned suite of Australian Standards aid the commercialisation and network integration of emerging energy technologies with limited dependence upon regulatory or legislative interventions
- Technological and commercialisation challenges are effectively addressed through open standards that facilitate interoperability whilst maintaining a safe and secure power system

Key findings

Standards Australia were commissioned to:

- Determine the current state of Australian standardisation in the sector
- Identify urgent priorities
- Identify needs for further coordination
- Identify timeframes for standards development priorities

Finding 1: Critical gaps

A number of key gaps in standards required to enable the future requirements of the power system were identified. These include key areas such as interoperability, communications frameworks and protocols, control systems and protocols, data frameworks and protocols, electric vehicles and cyber security.

Finding 2: Standards for an open platform

The development of guiding principles in relation to the development of open standards can help provide interoperability and maximise access to resources and services.

Finding 3: Alignment with international standards

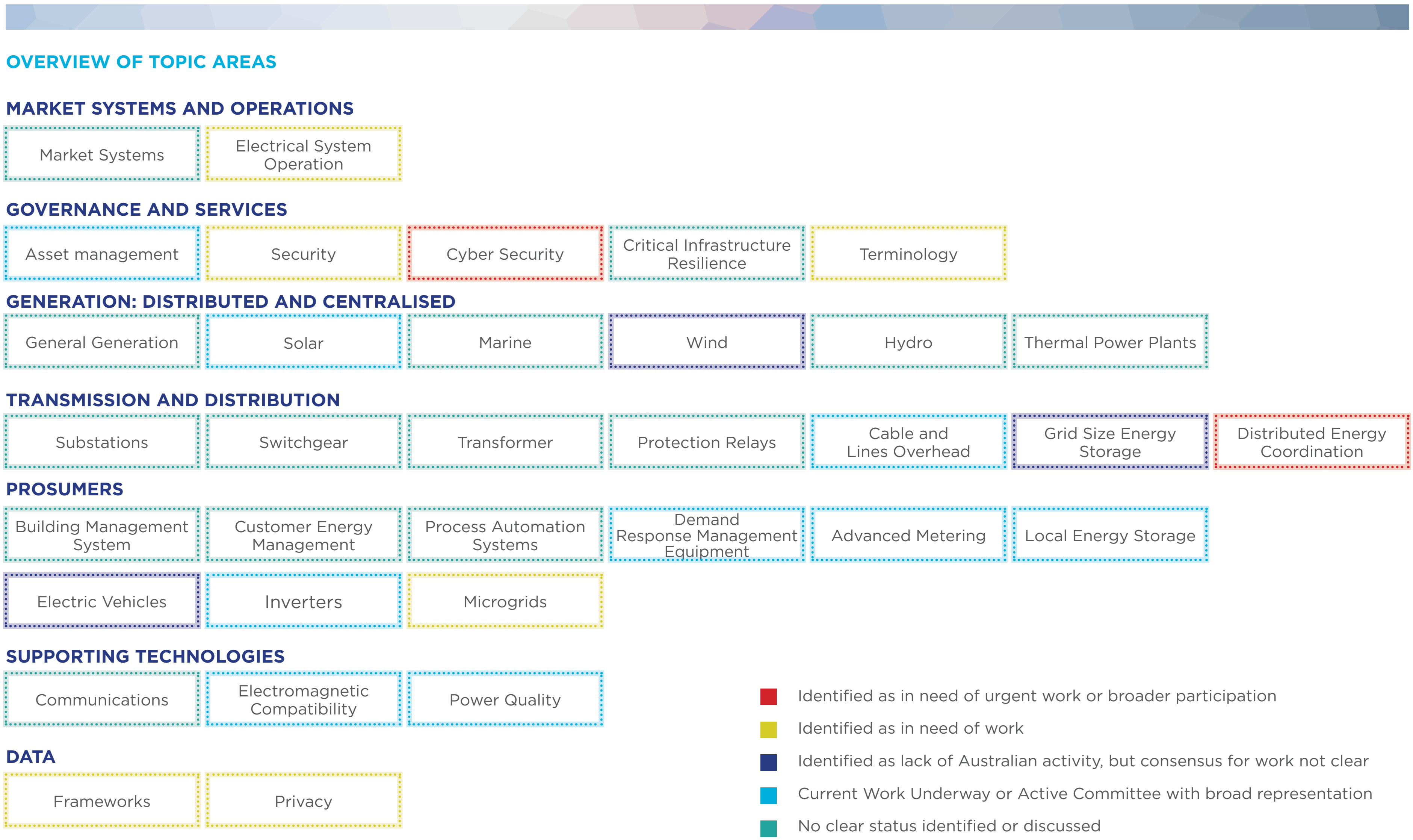
Alignment of national standards with international standards is important, as where major differences are found, they can constitute major impediments to new technologies and products being easily integrated into the Australian power system, which can impact speed of implementation and costs.

Reference documents

Documents that provide additional background to these findings include:

- Standards and the future of distributed electricity, Standards Australia (2017)

Figure 28: Snapshot of the current state of Australian standardisation



2017-27 Milestones

The Roadmap outlines a series of milestones which provide markers of progress over the decade toward the *Resilient 2027 Future State*. Each of the milestones are supported by a series of integrated actions.

Milestone 1: By 2018, develop and implement new guiding principles for all Standards Committees for the development and/or review of all future standards to enable the establishment of interoperability / open standards in a timely manner.

Guiding principles for the development of open standards will provide the foundation on which to support critical components of grid transformation such as interoperability, open data, communications and digital strategies.

Milestone 2: By 2018, ensure alignment of all relevant Australian technical committees with the International Electrotechnical Commission (IEC) committee structure.

Alignment of all relevant Australian technical committees with the IEC committee structure to ensure that any future Australian Standards are consistent with international frameworks making it easier for international manufacturers and suppliers to provide technologies that can be integrated into Australia's power system in a safe manner.

Milestone 3: By 2020, establish Australian Standards critical for the transformation of the industry, including standards for interoperability, communications frameworks and protocols, control systems and protocols, data frameworks and protocols, and cyber security)

Critical gaps in Australia's suite of standards that will enable the future requirements and functionality of the power system are required to be developed and published. Standards in key areas such as interoperability, data and communications protocols and cyber security will provide the foundation on which to support critical components of grid transformation.

Key benefits

The benefits associated with developing future standards that provide an open platform approach include:

One platform to serve all applications

With a multi-application platform, you build things once - such as the network and security architecture - then leverage them for each application. This ability to apply a common set of network, security, and integration services enables all key stakeholders with the ability to roll out new technologies, IT applications, products and services quickly and at low cost.

This approach will also ensure platform independence so that access to resources are not restricted to particular hardware platforms.

Product choice

By developing a layered approach through standards in implementing networking and other services, customers will have more choice of products including in home devices that can interoperate with intelligent grid devices.

This approach will also ensure application independence so that access to resources is not dependent on a single application.

Greater innovation

With a standards based, layered approach to product development and system interoperability, technology companies, networks and other industry partners can innovate for any given section of the power system and quickly deliver new features and functionality to customers, independent of each other.

This approach will also ensure architectural integrity so that the architectural framework for developments is robust and can be further developed in the future.

2017-27 Milestones and actions[18]

FOUNDATION						IMPLEMENTATION					
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INTELLIGENT NETWORKS & MARKETS

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TECHNICAL STANDARDS & REGULATIONS

Milestone 1

By 2018, develop and implement **new guiding principles for all Standards Committees** for the development and/or review of all future standards to enable the establishment of interoperability / open standards in a timely manner

- Establish industry working group to develop guiding principles for the development of open standards (2017–2018)
- Guiding principles finalised and implemented by all relevant standards committees (2018)

Milestone 2

By 2018 ensure **alignment of all relevant Australian technical committees** with the International Electrotechnical Commission (IEC) committee structure

- Review EL-034 "Power Quality" to broaden participation and visibility to mirror IEC TC 8: System Aspects for Electrical Energy Supply (2017)
- Review EL-034-05 "Grid Integration of Renewable Energy Generation" to broaden participation and visibility to mirror IEC TC8 SC8A: Grid Integration of Renewable Energy Generation (2017)
- Establish a subcommittee under IT-006 to examine IEC TC 65 62443 series on communication networks and cyber security and determine potential application in Australia (2017)
- Establish Joint subcommittee under JTC-1 Strategic Advisory Committee and the Australian National Committee to the IEC on data management (2017)
- Develop a new committee for mirroring IEC Systems Committee on smart energy (2018)

Milestone 3

By 2020, **establish Australian Standards critical for the transformation of the industry**, including standards for interoperability, communications frameworks and protocols, control systems and protocols, data frameworks and protocols, and cyber security

- Develop an Australian Standard consistent with IEC standard on cyber security (2018)
- Develop an Australian Standard consistent with IEC standard on communication protocols/frameworks (2018–2020)
- Develop an Australian Standard consistent with IEC standard on control system protocols (2018–2020)
- Develop an Australian Standard consistent with IEC standard on data management frameworks/protocols (2018–2020)

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Future workforce requirements

Background

Emergent technologies driving change in the electricity sector and supporting industries are already shifting the profile and skill requirements in the workforces of Distribution Network Service Providers (DNSPs), Transmission Network Service Providers (TNSPs), electrical contractors and workers in other electricity supply industry sectors.

The demand for such skill changes can be summarised through categorising critical skills and occupations into two workforce clusters:

» The digitally enabled workforce

» The traditional network workforce

It has been identified that meeting shifting workforce profile and its training and skills requirements will play a key role in the transformation of the existing power system, while continuing to deliver a reliable and secure system that ensures the safety of its employees as well as the general public.

Drivers of change

The key drivers of change identified during this research for the electricity supply and supporting industries are summarised into three distinct yet interconnected categories:

» **Key driver 1:** The emergence of technology with digitalised capabilities. Digitalisation of products, services and technologies are changing the way in which businesses service consumer needs and are manifesting themselves within the electricity supply industry in the form of distributed energy resources.

» **Key driver 2:** The integration of large scale renewable energy to replace traditional generation will require a change in the skills mix.

» **Key driver 3:** Increased consumer demands and the rise of the prosumer will mean that the technical customer service skills of network staff, third party providers and product installers of distributed energy resources will become increasingly important.

Resilient 2027 Future State

» By 2027, a coordinated effort at all levels of government, industry and the training sector has ensured the electricity sector and supporting industries have the right workforce, with the right skills, at the right time

» Focus on education mechanisms, core critical skills, skilling pathways and raising awareness of what will be different for the worker and consumer provides a complementary approach to upskilling and reskilling the workforce

Key findings

Energy Skills Queensland were commissioned to identify key mechanisms which enable sustainable workforce skill development pathways for the Australian electricity sector and supporting industries. Continuous learning will be critical and as such, the workforce of the future will need to be:

» Diverse

» Customer centric

» Innovative

» Digitally capable

» Agile

Finding 1: Higher level skills investment and prioritisation is required for existing power system workers

The speed with which emerging technologies are entering the market will result in a skills gap should the existing and future workforce not have adequate training and development. The complexity of embedding new technologies is higher generally in the early stages of adoption and as the product/service evolves the complexities narrow. The speed and complexity will increase the number of workers who will need to be upskilled/reskilled in the short to medium term. Without government training initiatives and funding support there are a number of workforce and consumer risks. Incorrect installation of technologies can have a range of impacts including safety, cost and reliability impacts on the Australian consumer.

Finding 2: Future skills investment is required for the development of new workers for the future power system

There are a number of training packages (VET) and university courses which are focused on core skill areas that will need to be adjusted to enable the delivery of *the Roadmap*. These are electrical, engineering, and ICT skills. The VET system will need to be responsive and flexible enough to keep up with emergent technology.

The university sector will also need to adapt, working with industry experts to redesign curriculum to address future skills needs. For example, there is no specific ICT degree that specialises in energy. The power systems engineer of the future will also require new skill sets not currently being widely taught in Australia.

Finding 3: Critical gaps

A number of key gaps in current skill sets that will need to be developed to enable the future requirements of the power system were identified. These include: systems thinking, ICT skills, data security; and customer focused service skills.

Reference documents

Documents that provide additional background to these findings include:

» Changing industry, a changing workforce: Electricity Network Transformation Roadmap workforce skilling impacts, Energy Skills Queensland (2016)

2017-27 Milestones

The Roadmap outlines a series of milestones which provide markers of progress over the decade toward the *Resilient 2027 Future State*. Each of the milestones are supported by a series of integrated actions.

Milestone 1: By 2019, complete a review and establish education and training package process and design.

The Electricity Supply Industry training packages under the VET system will need to be modified and the overall model reviewed to ensure it will be responsive and flexible enough to keep up with emergent technology.

The university sector will need to build on current activities to reshape the curriculum, working with industry employers and subject matter experts, to address future skills needs. For example, it is likely the power systems engineer of the future will require new skill sets not currently being widely taught in Australia.

Milestone 2: By 2022, complete a review and establish higher level skills investment and prioritisation for existing workers.

Funding levers at federal, state and territory levels will need to be reconsidered to enable the initial rapid transformation of appropriately skilled workers. By increasing the funding and priority of key higher level skills initiatives, industry will be more effective in transitioning its workforce safely and competently to the new world of work. As such it is pivotal that the existing workforce have access to additional funding for training in the short term to address these complexities.

Milestone 3: By 2021, establish and implement a skills and safety awareness campaign.

One of the key safety risk areas identified through the research is the area of new technology installation. Development and investment in a national education campaign, tailored to the specific regulations and legislation of each state and territory, to enable consumers to be informed about the type of worker they need. There is a large knowledge gap of what worker needs to be involved in each step, and has the potential for unskilled and unlicensed workers to carry out work.

Additionally, a complementary worker awareness and education campaign needs to be developed to ensure that individual workers, especially those in micro, small and medium sized businesses are made aware of the licences and additional training required to deliver work in these areas.

Key benefits

The benefits associated with developing future workplace requirements include:

Increased electrical safety

A competent electrical supply workforce will lead to the correct safety procedures being followed on the installation and maintenance of electrical products. This will in turn increase the safety of customers and the workforce with a reduction in electrical fault related injuries and deaths.

Increased value for customers

The correct installations and maintenance of electrical technologies such as distributed energy resources will lead to the consumer experiencing the full benefits of the technologies, including full functionality.

Skill ready workforce

A skill ready workforce is imperative to ensure the successful rollout of new technologies, products and services for the future power system. Successful outcomes will see Australia becoming a leading player within this industry that will have numerous economic benefits.

Enabling mass adoption of distributed energy resources

Customer satisfaction and adoption of new technologies, products and services will largely be created through the experience customers have with initial products. A well-trained workforce will ensure experiences will lead to the adoption of new products and services and their continuing valuation of services that the network can provide them.

2017-27 Milestones and actions[19]

FOUNDATION						IMPLEMENTATION					
2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2027+

INTELLIGENT NETWORKS & MARKETS

Develop essential information tools for a cost effective integrated grid, including: open standards, extended monitoring, advanced planning and feeder hosting analysis, and the mapping and locational valuation of distributed energy resources

Establish active distribution system operations and markets for technical stability and optimising investment by procuring distributed energy resource based grid support. Evaluate cost benefit analysis of procuring these services through a digital market platform

FUTURE WORKFORCE REQUIREMENTS

Milestone 1
Complete a review and **establish education and training package process and design**

- Review electricity VET and degree courses to ensure alignment to standards and regulatory requirements and relevant to the future workforce requirements
- Establish a nationally recognised accreditation process to create a suitable pathway for installers of small scale Distributed Energy Resources (DER) e.g. energy storage devices
- Establishment of a framework to monitor, review and update current training package development processes to ensure there is capability and capacity to update and design VET qualifications in a timely manner

Milestone 2
By 2022, complete a review and **establish higher level skills investment and prioritisation for existing workers**

- Establishment of a Workforce Skilling Taskforce to be established with contributions from Federal and State and Territory governments
- Update State and Territory VET investment plans to include recommended skill sets and qualifications, with adjusted funding parameters that currently rule out existing workers

Milestone 3
By 2021, **establish and implement a skills and safety awareness campaign**

- Develop and implement Consumer Skills Awareness campaigns
- Develop and implement Workers Skills Awareness campaigns

19 Milestone timings are developed as a national guide for Roadmap Implementation. Timing of milestones and actions will differ across jurisdictions and different network areas. Milestone timings are specified as a latest end date, but many will require early action and may be completed earlier than outlined

APPENDICES - REGIONAL ANALYSIS

Background

Given the breadth of analysis undertaken for *the Roadmap*, in order to reduce the complexity of this document we have largely focussed on national level outcomes when discussing the impacts of the various scenarios and issues explored. However, we conducted the modelling and analysis at regional scale, typically state and zone substation level, and outcomes at that level are, not surprisingly, more diverse. In this context, it is important to recognise that the projections are only one potential future and changes in key drivers could result in a range of possible outcomes

The major implication of the diversity of regional results is that some of *the Roadmap* milestones and actions, particularly the issue of timing, will need to be considered in the context of the region in which they are implemented. The following analysis highlights emergent issues in some states or regions, which may require modified timing of actions to suit local conditions, assuming the assumptions behind the analysis are realised.

Large scale renewable generation

Projected renewable generation as a share of state generation is shown in Figure 29 under *the Roadmap* scenario. Aside from Tasmania which has large hydro capacity, most of this renewable capacity is expected to be variable wind and solar generation. An important assumption in regard to this projection is that they are based on legislated rather than policy positions, for example, only the Victorian Renewable Energy Target was included in the modelling as a committed program assured by Government. Should other states legislate their renewable energy targets then results may differ considerably (e.g. the proposed Queensland target of 50% of consumption would encourage more renewable generation sooner in that state). The consequence of such potential changes for the efficiency of carbon abatement or the absolute level of Australian carbon emissions is similarly not assessed. The differences between the states also narrow if renewable generation included net imports, however we chose here to focus on the states' own generation.

There are two major implications which can be drawn from the projected state large scale renewable shares.

Finding 1: Some states will require earlier action to manage power system security.

Relative to other states, South Australia and Victoria will likely need to bring forward actions relating to managing power system security as they are expected to reach high variable renewable shares earlier.

Finding 2: Some states could see very significant generator construction programs required in compressed timeframes.

As states with currently low renewable energy shares accelerate renewable adoption, there are 5 year periods where they will need to sustain a renewable build rate of an average 1 gigawatt per annum. This high build rate occurs particularly in the eastern states and relates to periods such as 2030s and 2040s when there are expected to be significant existing multi-gigawatt coal-fired power capacity retirements.

As a large solar or wind project would tend to be around 0.2 gigawatts in size, the projected construction requirement is the equivalent of five projects per year for 5 years in jurisdictions like New South Wales, Victoria and Queensland. This intense level of project development, shifting between states at different times to coordinate with capacity retirements in those states will only be plausible and efficient with a clear and enduring greenhouse gas emission reduction policy environment. Without stable and enduring carbon policy supporting market responses, it is likely there would be significant upward pressure on the delivered cost of the installed capacity or less security of the timely development of needed generation.

Total battery requirements, including grid-scale

As part of reaching a zero emissions electricity sector by 2050, CSIRO modelled the requirements for energy balancing. This included utilising existing capacity including hydro power (where available in the state), deploying additional gas peaking capacity, exploiting the natural diversity in variable renewables and increasing deployment of battery storage at large-scale in addition to on-site battery storage. Strengthening of transmission can also play a significant role, however, to be deliberately conservative, CSIRO did not allow growth in state interconnectors to meet energy balancing needs.

A specific modelling tool was developed to determine the optimal amount of battery storage required in each state. Given the computational intensity of the analyses, the storage optimisation model was only applied at each decade interval. However, this was sufficient to conclude some broad trends and relationships and ensure that costs of storage could be incorporated into *the Roadmap* system costs.

Finding 3: Battery storage may begin to contribute to an optimised energy mix when renewable shares are in the range of 30 to 50%.

Figure 30 shows simulations of the required ratio of battery capacity to variable renewable generation capacity to achieve energy balancing for a given renewable energy share, by state (based on analysis as demonstrated in Figure 29). It indicates that battery storage is generally not required until high levels of renewable energy share are achieved and may form part of an optimised system when renewable share reaches 30-50%.

Figure 29: Projected renewable generation as a share of state generation under *the Roadmap* scenario.

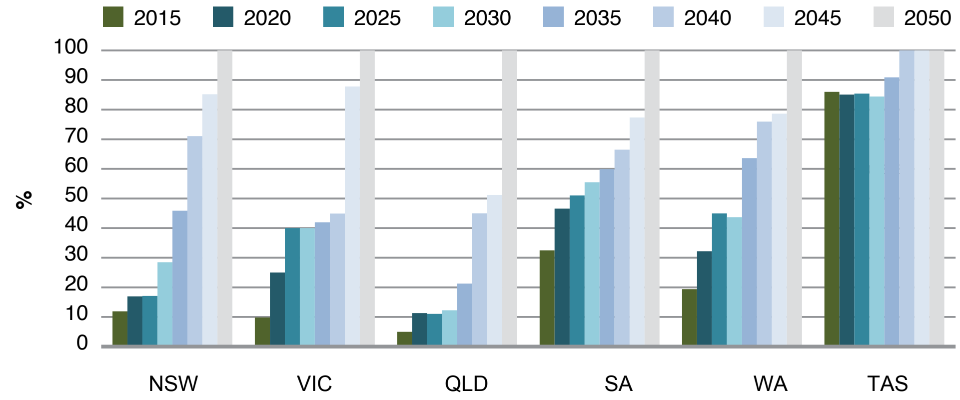
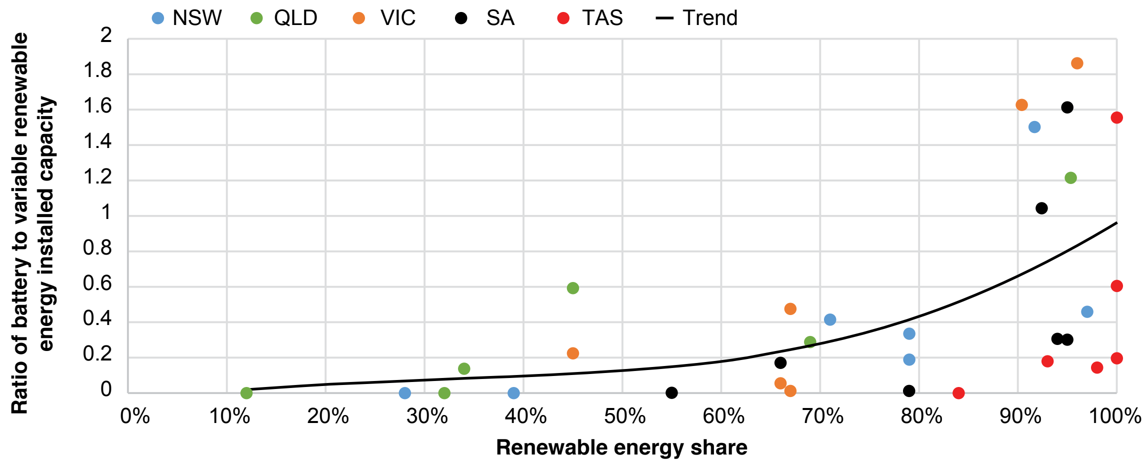


Figure 30: Projected ratio of battery capacity to variable renewable generation capacity to achieve energy balancing for a given renewable energy share, by state.



The data also indicates more than one possible storage level within each state and renewable share. This is because the storage optimisation tool evaluated alternatives to battery storage capacity development – i.e. building more peaking gas or 'overbuilding' variable renewable energy capacity (albeit with consequentially lower average capacity factor). In some cases, these options were projected to be more cost effective than building additional storage.

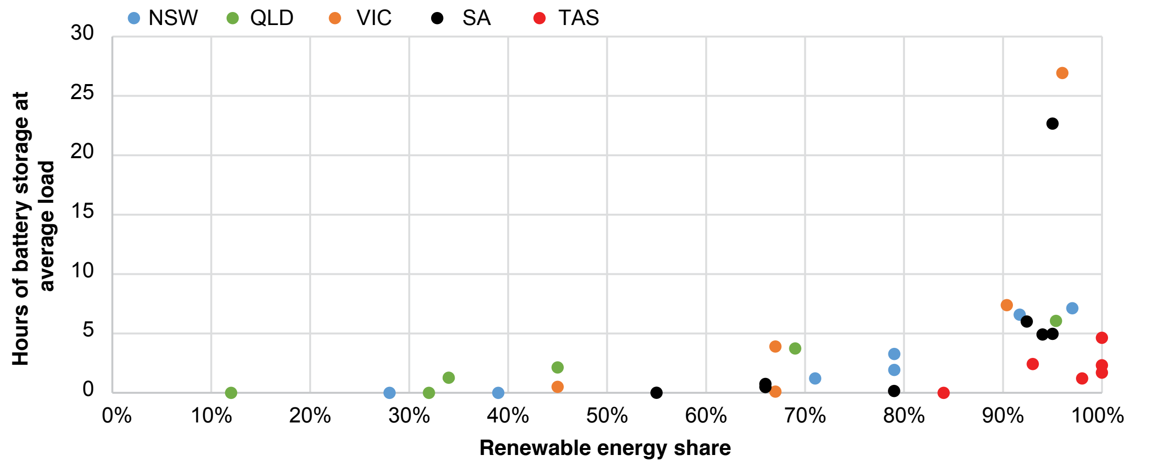
As the renewable energy share approaches 100%, the amount of battery storage increases non-linearly and approaches an average ratio of 1 to 1 with installed capacity of variable renewables. However, there is significant variance around this average ratio by state which reflects the character of renewable resources available. Tasmania generally requires a much lower ratio due to its large existing hydro power capacity and there are circumstances where New South Wales and South Australia may be able to deploy a lower ratio of batteries. Queensland and Victoria require higher ratio possibly reflecting poorer wind resources in the former and solar resources in the latter. This analysis was not a comprehensive generation optimisation study and further analysis of more diverse weather years would be required to draw definitive conclusions. Similarly, there will be a requirement to ensure inertia and system strength are also addressed with high levels of variable renewable energy share.

Finding 4: Gas or biogas peaking plant are more cost effective than adding additional storage capacity in circumstances where a substantial renewable generation shortfall extends for more than a third of a day.

To provide more insight into the analysis we also plot the hours of battery capacity at average state load against the renewable share in Figure 31. The analysis indicates that up until 80% renewable share, less than five hours of battery storage at average state load are required to support energy balancing working together with the existing dispatchable technologies remaining – hydro, gas and coal fired power.

However, approaching 100% renewable share, with the exception of Tasmania, battery storage hours require non-linear increases. We found in some cases the battery requirement becomes very large relative to the load, at greater than 20 hours. In these cases, it was concluded that additional gas peaking capacity would be more economic (and biogas was used when the emission constraint did not allow for natural gas). The total capacity of gas peaking plant required was not equal to peak demand. Rather since the peak demand day always has good sun in summer peaking states the required peaking capacity was around 60% peak demand. In Tasmania, which is winter peaking the requirement is less due to existing hydro capacity

Figure 31: Projected hours of battery storage required to achieve energy balancing for a given renewable energy share, by state



Compared to Figure 30 there is a greater alignment of estimated battery requirements when viewed from the perspective of average load rather than the ratio of battery capacity to installed variable renewable generation capacity. This indicates that while variable renewable generation creates a need for additional battery storage it may not necessarily be installed via a formula relating to installed capacity. Rather the total battery requirement more strongly relates to being able to meet average state load for an increasing number of hours.

The role of state interconnectors

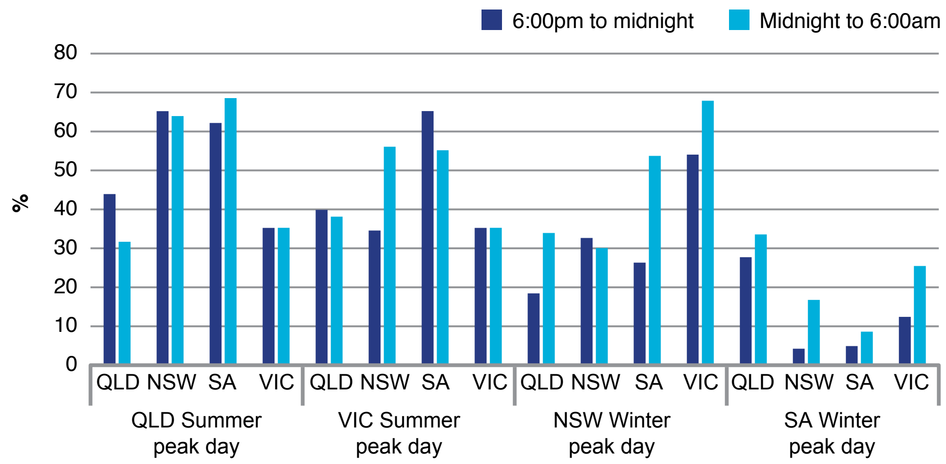
Finding 5: The diversity of variable renewable generation, particularly wind generation, across regions during summer and winter peaking conditions, suggests a stronger role for state transmission interconnections.

While, to be conservative, the modelling did not include growth in state interconnectors to meet energy balancing needs, our analysis of the diversity of state renewables can provide some guidance as to where stronger interconnection is likely to be useful. The system modelling found that a combination of wind and solar photovoltaic generation was efficient. Solar provides a relatively economic and predictable daytime supply in all states. However, a significant contribution from wind power is crucial to fill in the supply gaps at night together with storage and dispatchable gas capacity.

Figure 32 shows the average coincident capacity factor of wind generation on the summer and winter maximum demand days in selected demand regions. It shows that on their respective summer peak days, Queensland and Victoria would benefit from stronger interconnection with New South Wales and South Australia to access evening and night wind generation. In winter, the roles are somewhat reversed. On the New South Wales winter maximum demand day, it would be beneficial for system balancing purposes to have stronger interconnection to South Australia and Victoria.

On South Australia's winter maximum demand day, Queensland and Victoria wind power could supply the strongest support to that state's system balancing. Overall, it appears likely, based on the diversity of wind generation, that a case could be explored for strengthening a number of connections across the Eastern States as the share of variable renewables increases. Strengthening links to Tasmania would be more likely to be motivated by access to renewable hydro generation and storage capacity.

Figure 32: Historical (2009-10) coincident wind generation capacity factors on winter and summer maximum demand days in selected states

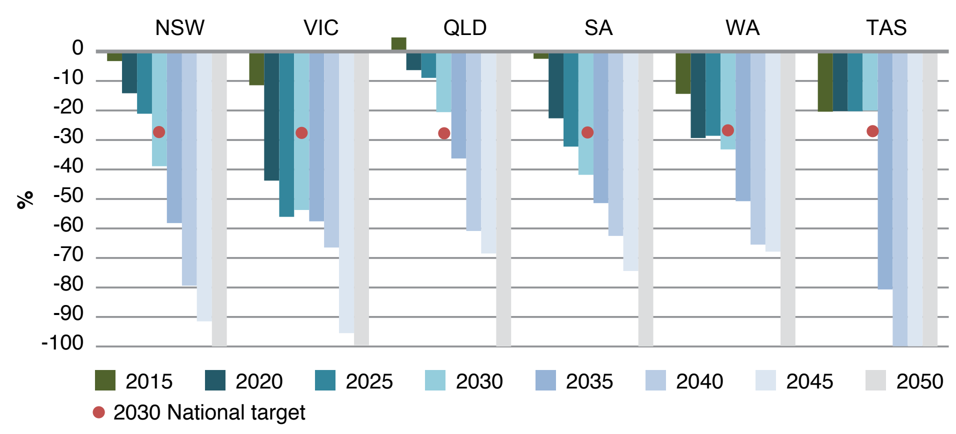


Greenhouse gas reduction

Due to higher costs of abatement in some non-electricity sectors, *the Roadmap* proposes that the electricity sector will need to achieve more than the national 2030 target of 26-28% below 2005 levels, aiming for at least a 40% reduction which represents an approximate linear path towards zero emissions by 2050. By 2015, the latest year for which emission reporting is available, the electricity sector had already achieved a total 5% reduction on 2005 levels with reductions in some states offsetting increased emissions in Queensland. Immediately beyond 2015 all of South Australia's coal fired power was closed in 2016 and the Victorian Hazelwood power station is now scheduled to close in the first half of 2017, both of which considerably increase abatement in those states.

The abatement projected to be achieved in the period 2020 to 2050 to some extent mirrors the increase in large scale renewable generation technology adoption in Figure 29 but not completely. Natural gas also plays a significant role, together with existing hydro power in reducing state greenhouse gas emissions intensity and providing the necessary energy balancing required in a high variable renewable energy environment.

Figure 33: Projected state greenhouse gas emission reduction relative to 2005 levels.



Distributed energy resources adoption

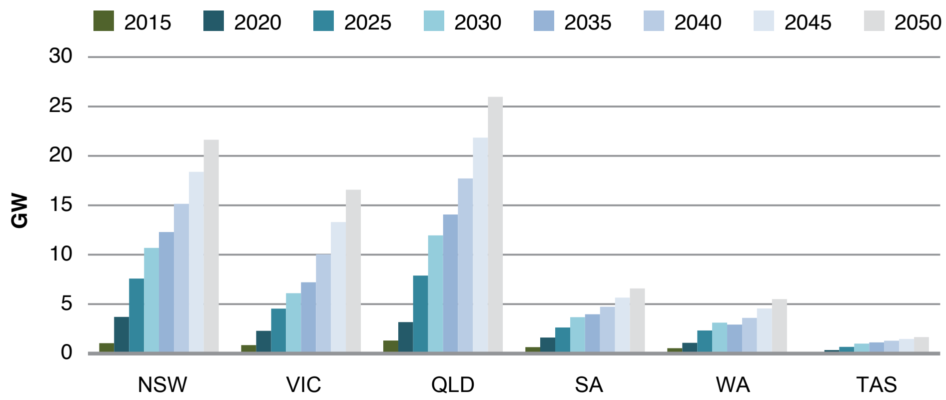
Finding 6: Projected higher rooftop solar capacity reflects both expected increasing customer adoption and larger average systems sizes

Rooftop solar capacity reached just over 5.5 GW in 2016 with the state differences largely reflecting historical state subsidies, the relative solar irradiance and population sizes. Subsidies provided in South Australia and Western Australia have allowed those states to achieve high rooftop solar installation rates relative to their population sizes.

These were generally in the form of a guaranteed price for rooftop solar exports to the grid that was well above the wholesale price of electricity.

The Roadmap assumes that there will not be a further round of specific state subsidies (and that the national subsidies available from the Small-scale Renewable Energy Target will also decline to zero). Consequently, future rooftop solar adoption will be increasingly driven by customers evaluating the merits of ownership on a non-subsidised basis, rather than any state specific policy interventions.

Figure 34: Projected installations of rooftop solar by state.



With solar costs continuing to fall and grid supplied electricity prices influenced by the cost of decarbonising the large-scale electricity generation sector, an increasing share of both residential and commercial customers are expected to install rooftop solar. Rooftop solar will be most attractive for customers in northern or western states where solar irradiance is higher. However, after this factor is taken into account, the relative differences in state installations reflect the population distribution and type of building stock. The higher absolute level of solar capacity reflects both increasing customer adoption and larger average systems sizes – average new system sizes have historically increased from around 2kW in 2010 to 5.5kW in 2016 and this trend is expected to continue.

Finding 7: Bundling of battery and rooftop solar systems together is expected to be the primary driver of battery storage adoption

While negligible to date, installations of battery storage for home or business onsite energy balancing have commenced in Australia such that they can be purchased as a standardised product with and without rooftop solar panels. To understand the state results, we first need to review the drivers for battery adoption overall.

The collection of installation data is in its infancy, however, it is widely reported that existing rooftop solar owners, seeking to get greater value from their existing investment are the primary early adopter group. Battery storage also represents an opportunity for customers to further reduce their dependence on the grid, which can be an important non-financial driver.

Future drivers of battery adoption are expected to become more complex over time. In the first period to the early 2020s, battery storage installation is expected to be primarily driven by the advantage of allowing rooftop solar owners to reduce the amount of solar output that has to be exported because demand on site is too low when the energy is available. As discussed above state government subsidised export prices for rooftop solar have largely come to an end. The prices received for exports without those subsidies are now around 6-11c/kWh which is well below the value of that electricity if the owner were able to use it on site (which we could value at prevailing retail prices for grid supplied electricity of around 22-27c/kWh).

From a purely financial point of view battery storage capacity is viable if it can be installed at a cost that is lower than the value of exploiting this ‘gap’ in solar export and grid import prices. That case is marginal at present. However, there is a strong expectation that the ‘gap’ is expected to widen over time and battery storage costs fall.

In the period of the mid-2020s to 2050, the motivation for battery storage installation under *the Roadmap* is expected to change as prices and incentives change. With a much larger cohort of customers receiving a service that includes a demand based tariff, batteries will be doing more than shifting rooftop solar output. In addition, they will be used to avoid network critical peak days (5 days per year) and daily peak pricing periods.

As the electricity market evolves further it is anticipated that battery owners may allocate control of their battery to other agents who can fine tune and aggregate battery operation to maximise the rewards they receive for assisting with energy balancing for both the local network zone substation and the state generation node.

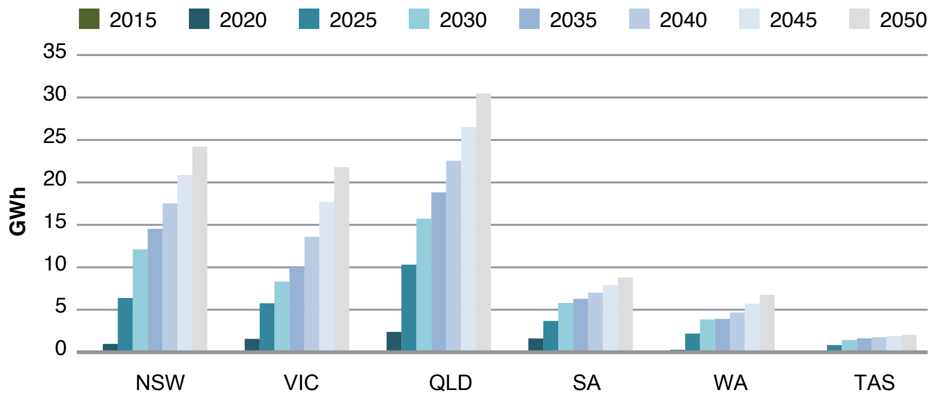
This wide ranging and very important role envisaged for battery storage means that the factors that will play into state level adoption include existing and future solar installations, the specific critical peak and daily peak prices offered in each state, the state opportunities for avoided network augmentation and the relative need for wholesale market energy balancing or variable renewable penetration.

Of these, rooftop solar adoption is the strongest factor as the projected installation in Figure 35 indicates given its similarity to Figure 34, but other factors will increase in importance over time.

Identifying zone substations potentially under stress

Finding 8: While South Australia is most at risk of reverse power flow associated with high rooftop solar adoption, other states, or particular substations within a state, are expected to follow over time, making it a growing national issue.

Figure 35: Projected installations of on-site battery storage by state



One of the key challenges *the Roadmap* seeks to meet is to maintain system security and reliability whilst achieving other goals. *The Roadmap* did not undertake any detailed power quality modelling which could pin-point specific power quality issues as this requires specialised high temporal and spatial resolution modelling. However, to provide some indication of when different regions may need to address power quality issues at the distribution level, we reviewed the projected load at each of the approximately 2000 zone substations in Australia (excluding the Northern Territory).

The load at each zone substation was calculated based on background growth derived from applying AEMO's demand forecasts and *the Roadmap's* projections of the adoption of distributed energy resources such as rooftop solar and onsite battery storage. If there are no other changes, high shares of rooftop solar will hollow-out the load during the middle of the day, leading to rising voltages on the local distribution system and could eventually lead to reverse power flows between regions. However, *the Roadmap* finds that there will be significant deployment of battery storage as customers seek to capture greater value from their solar systems and respond to incentives provided by networks and other system actors. The addition of storage allows a zone substation to potentially absorb a higher penetration of solar without running into issues. However, this requires coordinated action to provide incentives or rewards for a useful level of storage to be installed, and for the available capacity to be operated in a way that addresses zone substation level needs and local congestion.

CSIRO reviewed the relationship between rooftop solar share of total annual load at the zone substation and reverse power flows as a general indicator of other power quality issues. It was found that reverse power flows occurred at 30% rooftop solar load but were common from around 40% of load. We then examined when each substation, during the period to 2050, to determine when they reach this 40% threshold. The results are shown in Figure 36.

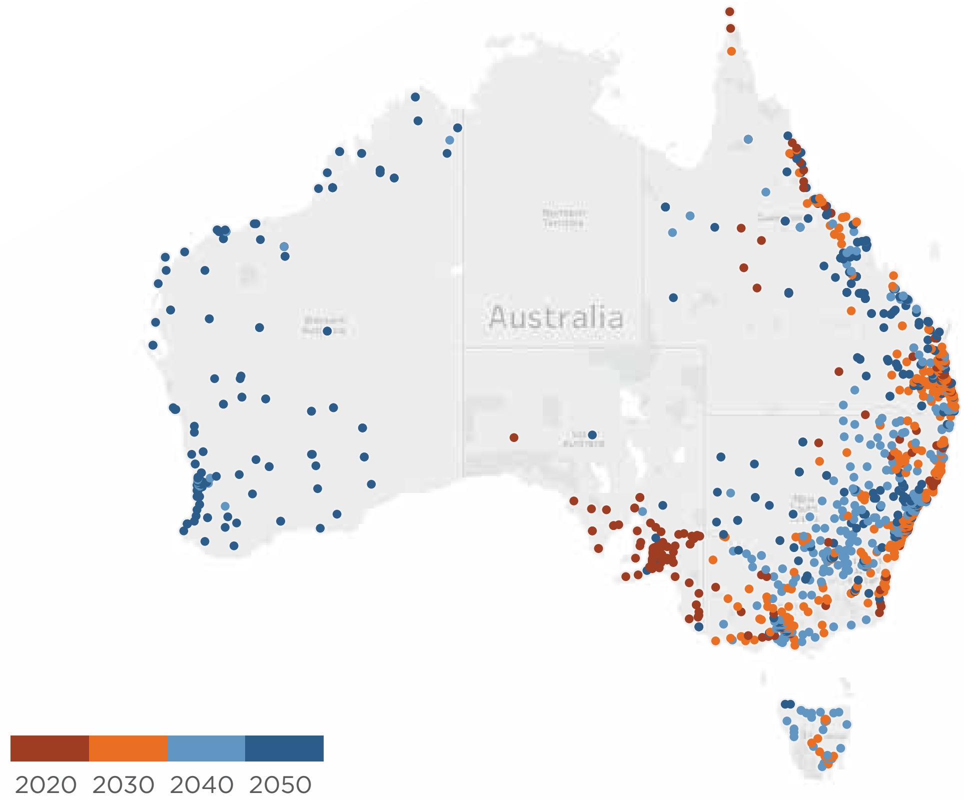
This zone substation analysis indicates that zone substations in South Australia have already met the threshold or will do so around 2020. The remainder of the Eastern states will have a significant share of substations over the threshold by around 2030, more so in the populated areas of the coast, but not exclusively so. Western Australian substations tend to meet the threshold from the 2040s, reflecting projected slower changes to electricity pricing in the 2030s (the renewable generation share is not increasing as fast or putting as much pressure on retail prices as other states during this period).

Reference Documents

Documents that provide additional background to these findings include:

» Economic benefits of the Electricity Network Transformation Roadmap: Technical report, Brinsmead, Graham and Qiu (2017)

Figure 36: Projected decade in which each zone substation will reach a threshold penetration of rooftop solar adoption (40%) indicative of reverse power flow.



APPENDICES - SUPPORTING REPORTS

Electricity Network Transformation Roadmap publications can be downloaded from **www.energynetworks.com.au/roadmap**

Section 2: Program evaluation and benefits

» Economic benefits of the Electricity Network Transformation Roadmap: Technical report, Brinsmead, Graham and Qiu (2017)

Section 3: Customer oriented networks

» Electricity Network Transformation Roadmap: Interim Program Report (2015)

» Electricity Network Transformation Roadmap: Customer Engagement Handbook (2016)

» Network business model evolution: an investigation of the impact of current trends on DNSP business model evolution, Accenture (2015)

» Insights from global jurisdictions, new market actors & evolving business models, Accenture (2016)

Section 4: Customer safety net

» Power Transformed, Consumer Action Law Centre (2016)

Section 5: Carbon & renewable policy options

» Enabling Australia's Cleaner Energy Transition, Energy Networks Australia (2016).

» Australia's climate policy options: Modelling of climate policy scenarios for Energy Networks Australia, Jacobs (2016)

Section 6: Efficient capacity utilisation

» Efficient capacity utilisation: transport and building services electrification, Graham and Brinsmead (2016)

» Gas-electricity substitution projections to 2050, ClimateWorks Australia (2016)

Section 7: Pricing and incentives

» DER simulation platform technical report, Energeia (2016)

» Economic benefits of the Electricity Network Transformation Roadmap: Technical report, Brinsmead, Graham and Qiu (2017)

» Unlocking value for energy customers: Enabling new services, better incentives, fairer rewards, Energeia (2016)

» Unlocking value: Microgrids and Standalone power systems, Energeia (2016)

Section 8: Regulatory and policy frameworks

» Future regulatory options for electricity networks, Cambridge Economic Policy Associates (2016)

Section 9: Power system security

» Future Power System Security Program: Progress Report, AEMO (2016)

» Economic benefits of the Electricity Network Transformation Roadmap: Technical report, Brinsmead, Graham and Qiu (2017)

» Electricity Network Transformation Roadmap Grid design, operation, platform & telecoms report, EA Technology (2016)

Section 10: Grid transformation

» The embedded generation project: Final Report. Marchment Hill Consulting & CSIRO for Energy Networks Australia (2015)

» Electricity Network Transformation Roadmap Grid design, operation, platform & telecoms report, EA Technology (2016)

» Electricity Network Transformation Roadmap innovation gap analysis and plan, EA Technology (2016)

Section 11: Network optimisation and platforms

» Electricity Network Transformation Roadmap Grid design, operation, platform & telecoms report, EA Technology (2016)

» Distribution systems in a high DER future: Planning, market design, operation and oversight, De Martini & Kristov, Lawrence Berkeley National Laboratory (2015)

» Decision-Maker's transactive energy checklist, The GridWise Architecture Council (2016)

» Future market platforms and network optimisation - Synthesis report. Drawn from international consultant reports (2017)

Section 12: Technical standards and regulations

» Standards future of distributed electricity, Standards Australia (2016)

Section 12: Future workforce requirements

» Changing industry, a changing workforce: Electricity Network Transformation Roadmap workforce skilling impacts, Energy Skills Queensland (2016)

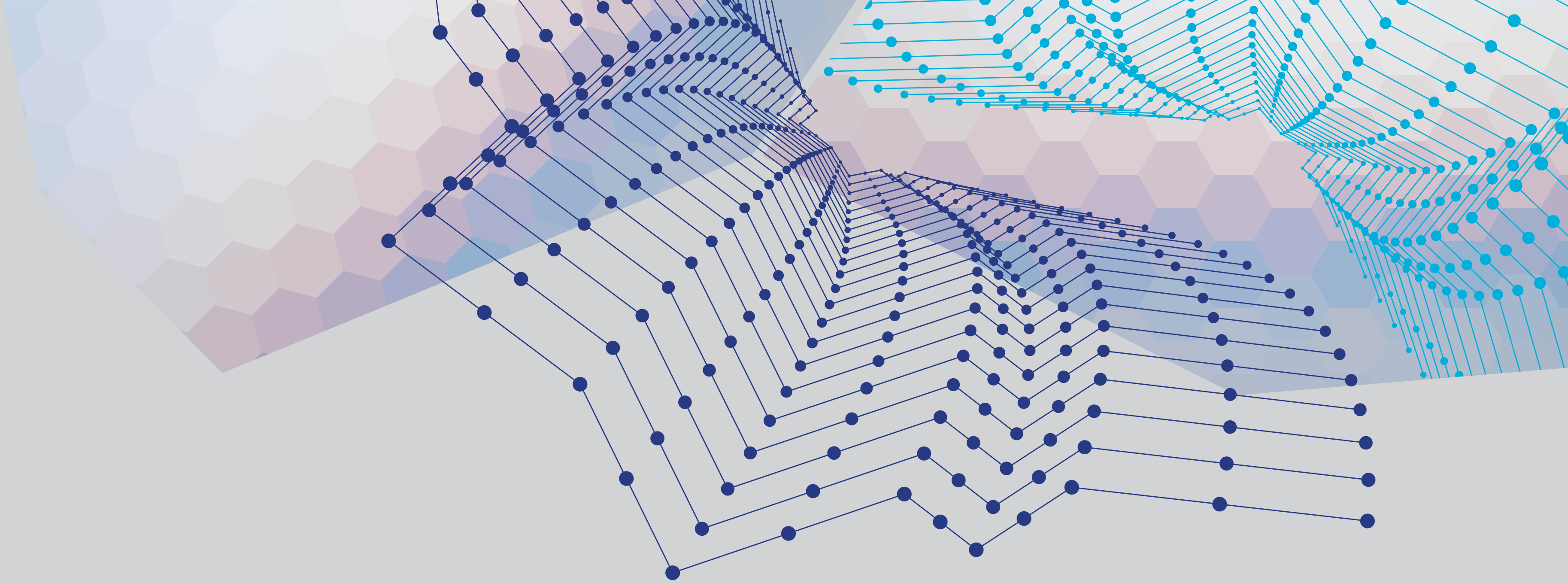
Appendices - Regional analysis

» Economic benefits of the Electricity Network Transformation Roadmap: Technical report, Brinsmead, Graham and Qiu (2017)

LIST OF FIGURES

LIST OF ACRONYMS

AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
ANO	Advanced Network Optimisation
CCS	Carbon Capture and Storage
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DER	Distributed Energy Resources
dNOM	Digital Network Optimisation Market
DNSPs	Distribution Network Service Providers
DSO	Distribution System Operator
EIB&C	Emission intensity baseline and credit scheme
ERF	Emissions Reduction Fund
FCAS	Frequency Control and Ancillary Services
FPSS	Future Power System Security program
IEC	International Electrotechnical Commission
IMO	Independent Market Operator
LRET	Large Scale Renewable Energy Target
NEM	National Energy Market
NOM	Network Optimisation Market
NSP	Network Service Provider
PV	Photovoltaic (e.g. solar panels)
RAB	Regulated Asset Base
RET	Renewable Energy Target
RiT-D	Regulatory Investment Test - Distribution
RoCoF	Rate of Change of Frequency
SAPS	Stand Alone Power Systems
SCADA	Substation Control and Data Acquisition
SGAM	Smart Grid Architecture Model
SVCs	Static Var Compensator
TNSPs	Transmission Network Service Providers
TOTEX	Total Expense (Capital and Operational)
TSO	Transmission System Operator
TSS	Tariff Structure Statement
VRE	Variable Renewable Energy



Energy Networks Australia

CSIRO