Role of electricity networks in supporting the energy market transformation

Report prepared for Endeavour Energy

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Limitation of our Work

General Use Restriction

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Executive summary

Executive summary
Background, scope and approach

Background

We are in the midst of a transformation of the energy market:

- **Electricity generation is transforming** – Historically, the National Electricity Market (NEM) has been dominated by large coal generators, with some gas and hydro generation. There is a transition towards renewable generation creating structural changes in the market – generation is becoming increasingly dispersed and remote from demand centres, putting pressure on transmission networks
- **Electricity prices have risen significantly** – Over the last few years, wholesale electricity prices have risen and become more volatile across the NEM. This is due to a combination of generator closures, fuel cost increases, and transitional issues as we move to a system with higher renewables
- **Distributed energy resources (DER) are increasing rapidly** – Government subsidies and falling costs have seen rapid increases in uptake of rooftop PV, with the share of demand met by rooftop PV forecast to continue to increase. Other technologies such as batteries and electric vehicles will also change the way energy is used. Efficient take-up and use of these DER is critically reliant on advanced network operations and investments
- **Despite flattening demand, significant investments are required** in generation and network infrastructure to replace ageing generation assets with typically more geographically dispersed renewables, integrate renewable energy (both large and small scale), and support the transition to renewable energy.

A strong electricity network is critical to achieving this transformation at least-cost, by facilitating the efficient production, transportation and use of electricity.

Scope of work and approach

Deloitte was engaged by Endeavour Energy to analyse the role of electricity networks in supporting the energy sector transformation, and associated economic activity. Our approach to the analysis was as follows:

- Review current and future changes in the market and identify the role of networks in facilitating the energy market transition
- Consider the investment in networks required to support an efficient, least-cost transition
- Assess the implications for the energy market and the economy, in the event that optimal investment in networks to support the transition does not go ahead. Specifically, we have defined two alternative investment scenarios for the analysis:
  - **Base Case –** energy market transformation progresses with efficient network investment supporting new utility-scale generation and the take up and utilisation of DER
  - **Network Underinvestment scenario –** barriers to investment in networks impede the connection of a least-cost generation portfolio and optimal use of DER

Our analysis was projected for approximately the next 20 years (to 2037), and was supported by our core modelling tools:

- The Deloitte Energy Market Model (DEMM), to model the energy transition scenarios and estimate the impact on sector investment and prices
- The Deloitte Access Economics Regional General Equilibrium Model (DAE-RGEM), to estimate the impact on key economic indicators (such as gross state product and employment).

Executive summary

Supporting a least-cost wholesale market transformation

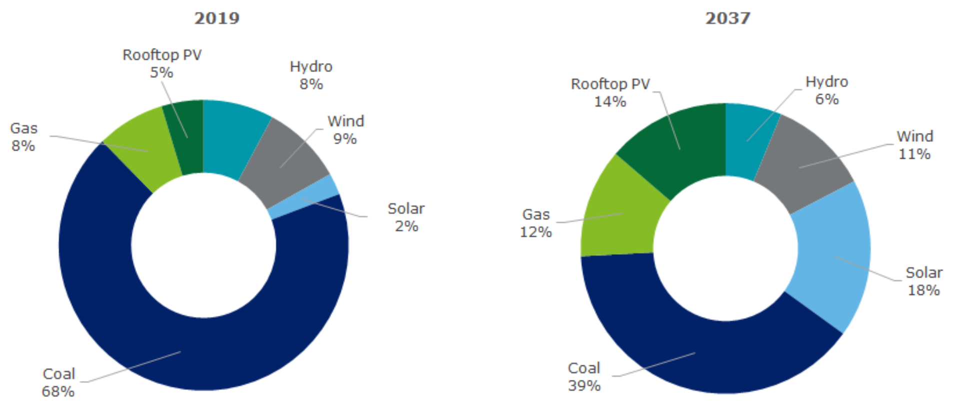
Decarbonisation of the wholesale market

The NEM is transforming from a model of centrally-dispatched, fossil-fuel based generation to one where a significant proportion of generation comes from renewable sources, and is either unscheduled (i.e. rooftop PV) or semi-scheduled (i.e. utility scale wind and solar).

In our recent report, *Energy Accelerated – a future focused Australia,* we set out a range of potential energy futures for Australia, showing four potential energy mix scenarios driven by alternative policy approaches and action by industry (Deloitte, 2018).

In this report, we present a 'Base Case' forecast of the energy mix over the next 20 years, with a least-cost pathway defined by significant uptake of rooftop PV and utility scale renewables, supported by some storage and flexible gas (Open Cycle Gas Turbine, or OCGT).

Forecast change in the generation mix (energy generated) – Base Case



Source: AEMO 2018b; Deloitte

Transmission networks need to adapt to more dispersed and remote generation sources

The geographic dispersion of new capacity means greater reliance on transmission, with several means by which targeted transmission investments can play a role in delivering the transition at least-cost:

- Increased interconnection capacity, to support reliability and security of supply through diversity of new generation sources. Diversity of supply can also defer the need for investments in generation.
- Network extensions to allow the connection of new, geographically diverse renewable generation and reduce congestion – as defined in the Australian Energy Market Operator's (AEMO) REZs. This supports the development of renewable generation and **renewable energy zones** in shallow mode (i.e. where generators only pay for their own connection cost – as opposed to 'deep mode', where generators also contributed to reinforcement of the existing network), and broader network upgrades to reduce network congestion are facilitated through AER's regulatory investment test process.
- Enhanced voltage and frequency control, systems that allow for better real-time forecasting, faster scheduling and ancillary services to support growing uptake of **small-scale decentralised generation** and decreasing demand in NEM.

Executive summary

Optimising the use of DER and supporting innovation

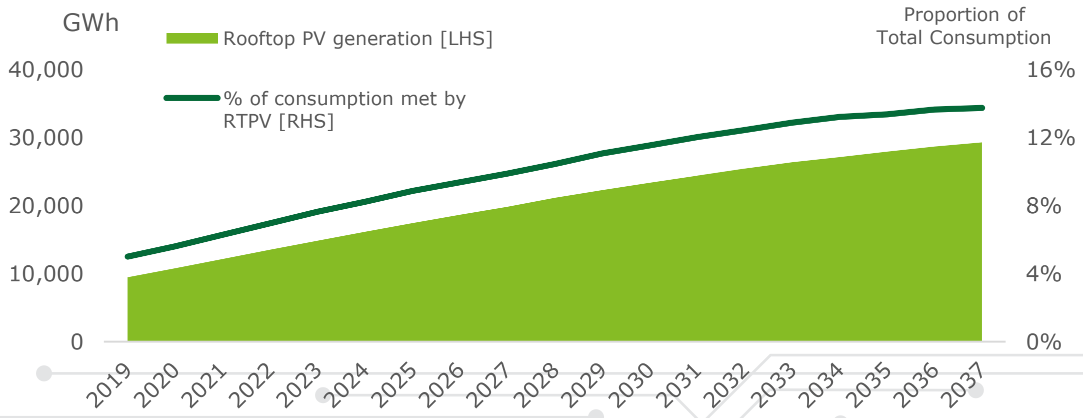
Changes in the way consumers use and produce energy

Falling technology costs, high energy prices and supportive policies have seen customers increasingly investing in rooftop PV to exercise greater control over their energy use and bills.

2017-18 was a record year for growth in rooftop PV installations, with about 1,300 MW of new capacity installed (around 260,000 systems), bringing total rooftop PV capacity across the NEM to around 6,500 MW. Nearly a third of all homes in QLD and SA now have solar panels on their rooves, with other States at around 15% penetration (CER 2018).

The output from rooftop PV is now equivalent to around 5% of the NEM's total energy consumption needs and is expected to reach roughly 14% over the next 20 years (AEMO 2018b). Cost reductions could also see rapid uptake of small-scale batteries and electric vehicles.

Forecast take-up of rooftop PV (GWh)



Source: AEMO 2018b; Deloitte

Targeted investments in distribution are required to support and benefit from rapidly increasing DER

The efficient take-up and use of DER can potentially provide a range of benefits to the network, for example, flattening load and contributing to the optimal use of the network, avoiding augmentation expenditure and pushing back investments in generation capacity. To achieve these benefits, targeted investment in networks will be required to ensure that the network is ready to manage high levels of DER, and also to ensure that customers can continue to invest and receive benefits.

Proactive management of DER (also known as Market Orchestration (ENA 2017)) requires investments in Advanced Distribution Management Systems (ADMS), which could include a range of investments and actions, such as:

- Enabling various Advanced Network Optimisation functions, from basic aggregation and procurement models to more sophisticated services that can be provided by DER, such as **Virtual Power Plants**
- **Managed charging and discharging** of batteries and electric vehicles (smoothing demand peaks), supported by cost-reflective tariffs that signal the broader costs of coincident demand
- Enabling bi-directional flows and **reactive power injection**
- **Voltage monitoring and voltage regulation**. These measures include remote switches, remote tap changers, capacitor banks, voltage regulators and remote static VAR compensators (for fast acting reactive power), advanced inverters that can more effectively maintain system stability in the presence of high DER.

While these investments have the potential to significantly reduce costs in the long-run, we note that many will require upfront spending, and will not necessarily be directly aligned with networks' regulated functions and service obligations as defined in the National Electricity Rules (NER).

Executive summary
Impacts on the energy market

Despite some initial cost reductions, costs are higher over the long-term in our Network Underinvestment scenario

We assessed the impact on the energy sector from an underinvestment in network infrastructure using the Deloitte Electricity Market Model (DEMM). In our Network Underinvestment scenario, we:

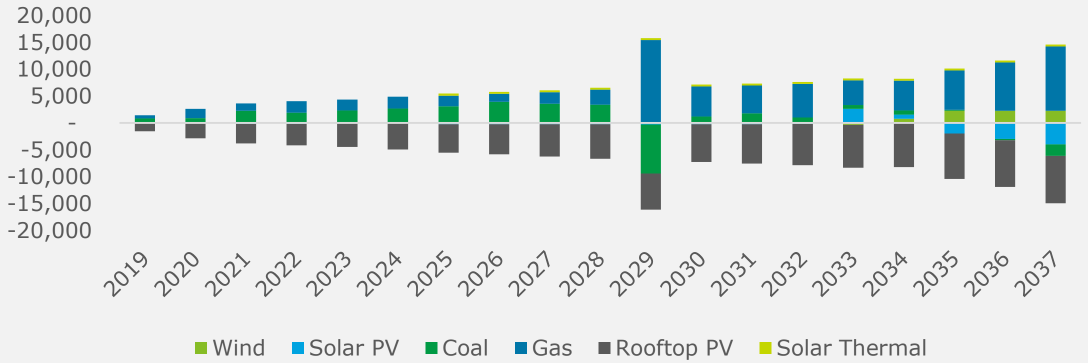
- Reduced distribution expenditure consistent with estimates of investment required to facilitate and optimise the update of DER – amounting to around a 15% per year reduction in capital expenditure, which we assume reduces both the take-up of, and exports from, rooftop PV
- Reduced transmission expenditure in accordance with certain capacity augmentations identified in AEMO’s Integrated System Plan, which limits the amount of generation that can be built in key areas
- Applied an annual growth figure to future network expenditure, consistent with the ENA’s estimates of network savings achievable from targeted network investments (which we assume are foregone).

Wholesale prices are consistently around 7% higher over the forecast period in our Network Underinvestment scenario, due to: (a) changes in the location of new renewable generation entering the market due to limited access to the most valuable renewable energy resources; and (b) changes in the generation mix, with more gas and coal used to make up for lower rooftop PV.

Reduced investment in networks initially puts downward pressure on prices. But over time, higher wholesale costs and an upward trend in network costs (due to increased needs for traditional augmentation expenditure) result in higher retail prices in the Network Underinvestment scenario.

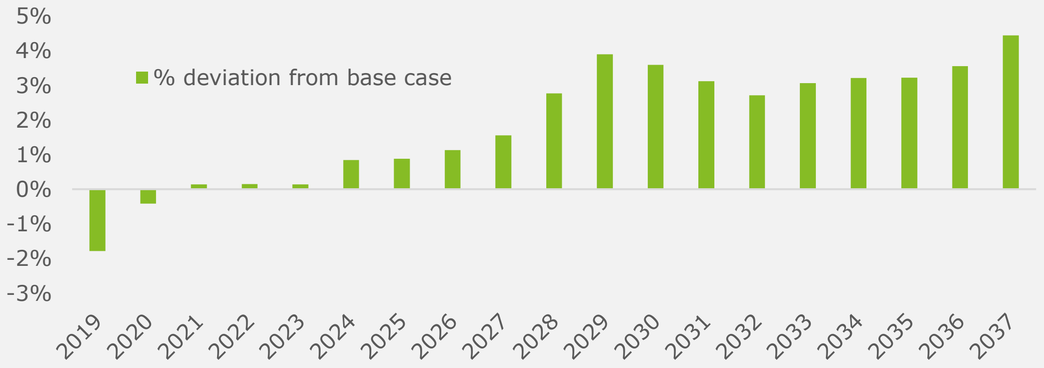
Post 2027, retail prices are on average around 3-4% higher in the Network Underinvestment scenario as compared to our base case. The lift in prices in 2029 is due to the Vales Point and Gladstone coal plants reaching their end of life. In practice there may be government measures to even out prices by staggering closures over several years.

Difference in fuel mix in the Network Underinvestment scenario relative to the base case, GWh



Source: DEMM.

Network Underinvestment scenario, % change in retail prices relative to the base case



Source: DEMM, Deloitte analysis.

Executive summary
Economic impacts

Role of electricity in the economy

Electricity plays an important role in powering industry, medium and small businesses and households and is likely to become more important in powering transportation in the future.

It follows that a limit on investment in electricity infrastructure that increases the price of electricity will result in a contraction in the Australian economy. The economic impacts are most not noticeable post 2027, when retail price increases begin to climb.

GSP outcomes are lower in the Network Underinvestment scenario relative to our base case

The cumulative reduction in Gross State Product (GSP) across the NEM States by 2030 is over $10 billion, and by the end of our forecast period (2037), this is forecast to nearly double to $20 billion.

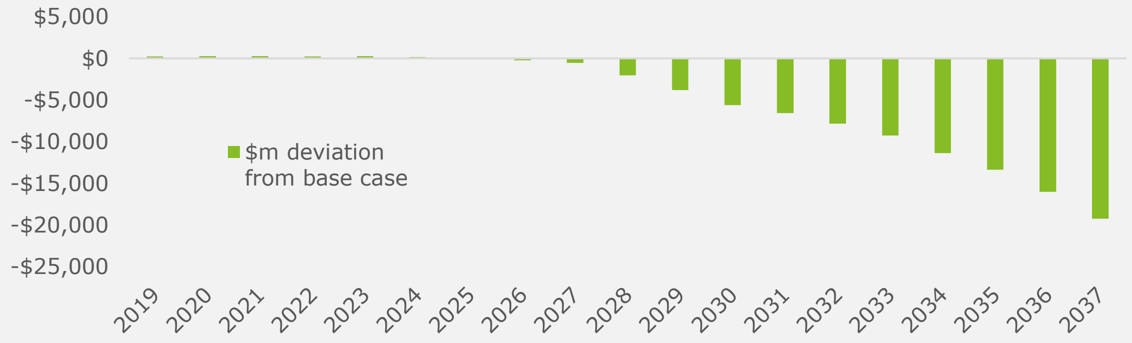
In terms of individual States, Tasmania is the most affected, while impacts in Queensland are relatively small. These results reflect both exposure to electricity prices through industry make-up, and also the size and complexity of the economy (with smaller economies such as Tasmania less able to absorb economic shocks than larger economies such as NSW).

Employment is initially steady, but falls significantly post 2027 in our Network Underinvestment scenario

The initial downward step in electricity prices in the first decade of the Network Underinvestment scenario results in a slight increase in employment across the NEM. In Victoria, where the initial price drop is slightly larger than in other States, employment peaks in 2027 at around 6,000 FTE (0.2%) higher than in the base case.

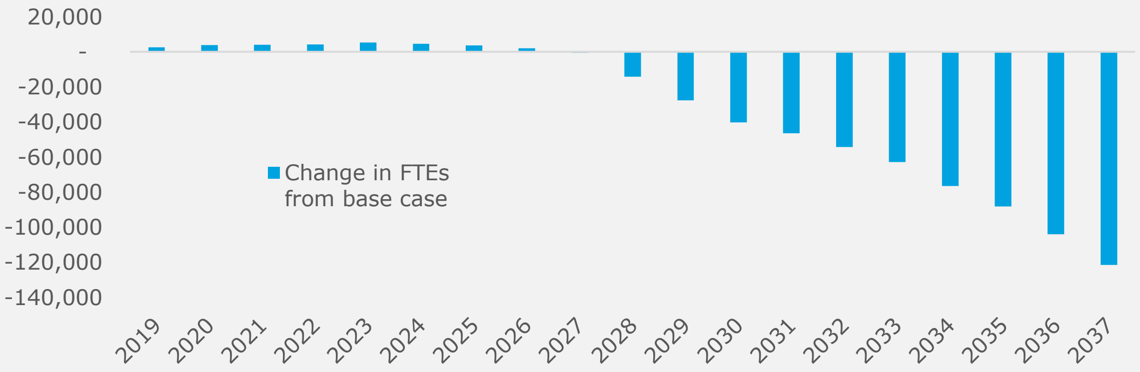
By 2030, employment is around 40,000 FTE lower across the NEM with all States seeing reductions in the order of 0.5%-1% over just a few years. This trend continues for the forecast period, with employment across the NEM down by around 120,000 by 2037.

Change in GSP in the NEM in Network Underinvestment scenario ($m)



Source: DAE-RGEM.

Change in employment in the NEM in Network Underinvestment scenario (FTE)



Source: DAE-RGEM.

1. Energy market transformation

Energy market transformation

Overview of the National Electricity Market

The National Electricity Market

The National Electricity Market (NEM) is the wholesale electricity market for the electrically connected states and territories of eastern and southern Australia. The NEM is one of the world's longest interconnected electricity networks, covering approximately 5,000 kilometres and supplying around nine million customers per year with 54.4 GW generating capacity (as of December 2017) (AEMO 2018c).

- The **transmission network** comprises around 40,000 km of transmission lines. The distance between the main population centres on the East Coast means that the transmission network is long and low-density. There are five State-based transmission networks, and six cross-border interconnectors linking the regions.
- There are 13 major **electricity distribution networks**, which combined operate around 735,000 km of distribution lines. Queensland, New South Wales and Victoria each have multiple networks, while the ACT, South Australia and Tasmania each have one major network (AER 2017).

The electricity networks are subject to economic regulation, with revenues set by the Australian Energy Regulator (AER). Under the national electricity framework, networks are constrained in their ability to own generation and "behind the meter" assets.

NEM regions, transmission network and distribution zones

Source: AER 2017

Energy market transformation

The NEM is transforming towards renewable generation

Role of electricity in the economy

The mix of electricity generation is transitioning from a system based primarily on centrally dispatched, synchronous generation (i.e. coal and gas-fired generation), to a mix of traditional fossil fuels and variable renewables (wind and solar):

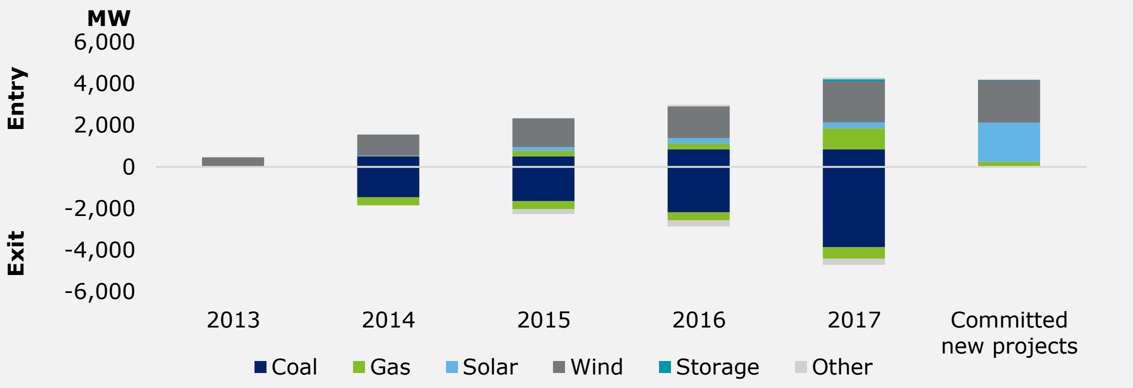
- 2,400MW of coal generation has been withdrawn from the NEM in the last few years, with another 2,000MW of announced withdrawals (AGL has announced closure of Liddell, its 2,000MW coal-fired power station in NSW, by 2022)
- Generation capacity provided by renewables such as wind and solar has increased considerably over recent years driven by government policy incentivising investment in these generation technologies, including the RET and state-based schemes, and underlying cost reductions.

There are a number of pressures on wholesale prices going forward

Going forward, there are a range of uncertainties and pressures on wholesale prices, which could shift future wholesale price outcomes up or down, such as:

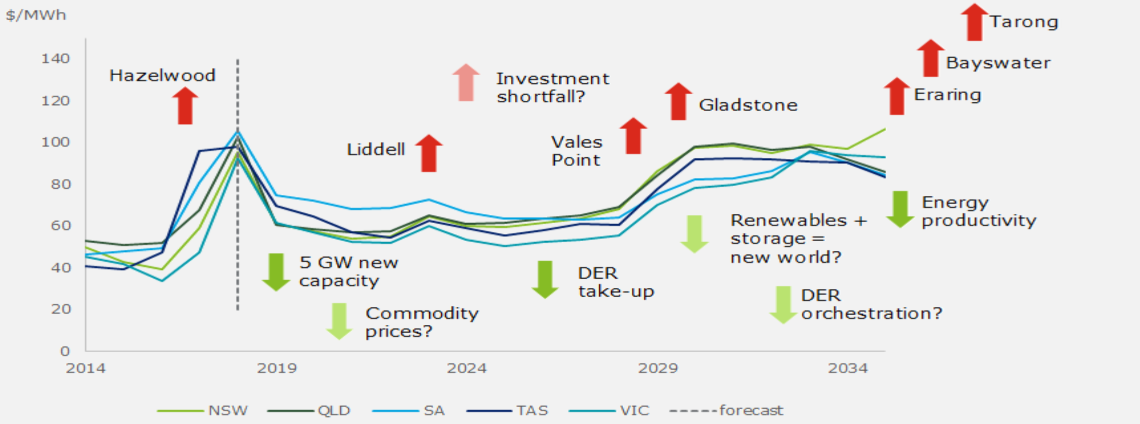
- Retirement of ageing coal-fired power stations – for example, these may be staggered to address price impacts
- Take up of distributed energy resources, which can put downward pressure on demand and prices
- Increasing take-up of utility-scale renewables, utilities-scale batteries, and how they interact in an energy-only market
- Commodity prices, with global coal, oil and gas prices increasingly impacting the domestic energy market
- Energy demand, and energy productivity (i.e., energy efficiency), and the implications for demand.

Recent changes in generation capacity, MW



Source: AEMO.

Pressures on wholesale prices going forward



Source: Deloitte.

Energy market transformation

Role of the networks

Transmission networks

Transmission networks transport electricity generated at large-scale power stations via high-voltage transmission lines to the distribution networks to supply customers.

The major assets comprising transmission networks include transmission lines, transmission (terminal) substations (including power transformers) and sub transmission substations to interface with distribution networks. In addition to these primary assets, transmission networks also have secondary systems equipment that assist in the control, protection and safe operation of transmission assets.

The projected transition in the generation market to substantial amounts of geographically dispersed renewable generation will place a greater reliance on the role of the transmission network. A much larger network footprint with transmission investment will be needed to efficiently connect and share these low fuel cost resources.

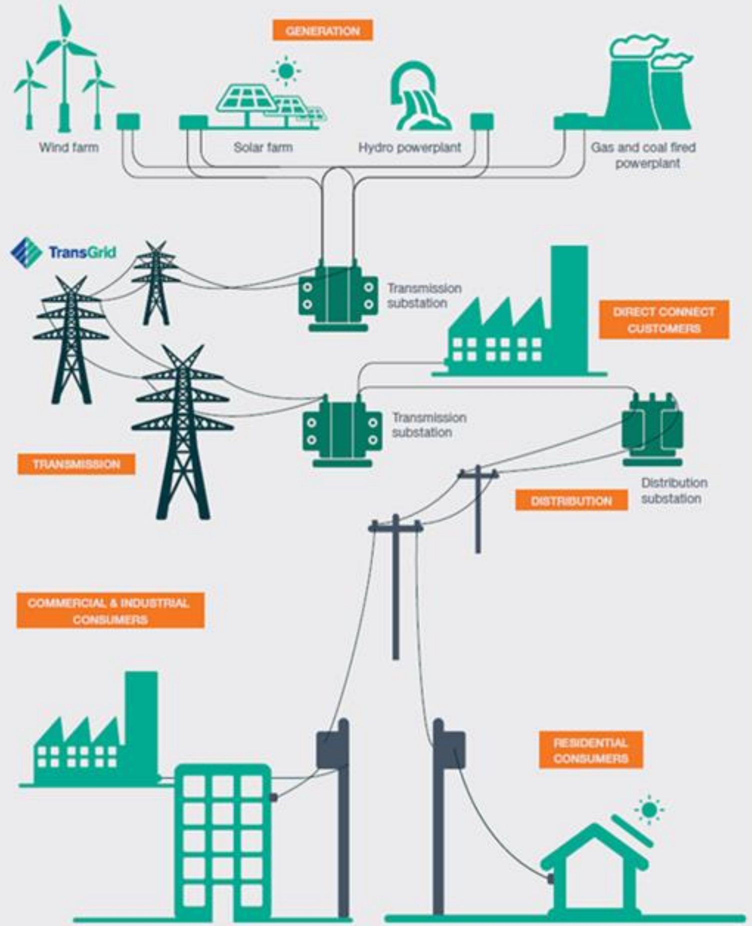
Distribution networks

Distribution networks take power from the transmission network and deliver it to towns, suburbs, homes and businesses.

The major assets comprising distribution networks are distribution feeders, zone substations, distribution poles and transformers including distribution management systems to monitor local outages, network condition.

With the growing uptake of distributed generation technologies such as rooftop PV and implications for the stability of the grid, distribution networks are faced with an increasingly challenging task of voltage and capacity management for safe and reliable operation of the network.

Schematic of power flows within and between the networks



Source: TransGrid 2015

Energy market transformation
Role of the networks

Role of networks in enabling the transformation

In this study, we consider two main areas for the role of energy networks in enabling the energy market transformation:

1. **Supporting a least-cost wholesale market transformation**

- Facilitating the efficient production and transportation of electricity
- Unlocking the most efficient solar and wind resources in the NEM
- Enabling the utilisation of geographically dispersed generation resources and promoting efficient competition for the supply of electricity

2. **Optimising the use of DER and supporting innovation**

- Connecting and facilitating the optimal use of DER, such as rooftop PV and batteries
- Supporting innovation and new services to assist consumers to manage their energy use.

These two areas broadly relate to transmission and distribution, respectively. However, we note that the increasing role of DER in meeting energy demand is likely to result in increased interactions between transmission and distribution.

In the following sections of this report, for each area, we consider:

- Current and future changes in the market and the role of networks in facilitating the energy market transformation
- The nature of investment required to support an efficient, least-cost transformation
- The implications for the energy market in the event of barriers to investment in networks.

1a. Supporting a least-cost wholesale market transformation

Supporting a least-cost wholesale market transformation

A decarbonised, decentralised energy market

Decarbonisation of the wholesale market

Historically, the NEM has been dominated by large coal generators, with some gas and hydro generation. There is a transition towards renewable generation creating structural changes in the market.

Over the next approximately 20 years (to 2037), 10.7 GW of thermal baseload capacity is expected to retire (9.7 GW of coal and 1 GW of gas) (AEMO 2018b). This amounts to nearly one quarter of total NEM consumption.

Based on current technology costs and forecasts, a least-cost pathway to replace this would be mainly comprised of utility scale renewables, supported by some storage, flexible gas (OCGT).

Our 'base case' forecast of the generation mix, derived from the Deloitte Electricity Market Model (DEMM) is consistent with the change in generation capacity, and forecasts the following trends:

- Coal's share in the generation mix will decline by nearly half, from 68% to 39%
- Utility-scale solar is expected to achieve the greatest cost reductions (around 50% over the period), and accordingly, in our forecasts, its share of the generation mix increases from 2% to 18%.
- The role of gas expands to play a firming role for new renewable generation capacity and partially fill the gap left by coal retirements.
- Wind generation capacity continues to grow in line with demand growth, retaining a similar share of generation output over the forecast period.

We consider this picture of the energy market transition to be reasonably conservative, as it is broadly aligned with other forecasts (e.g. AEMO's ISP), and represents a 'middle ground' approach when compared to the scenarios outlined in our recent report *Energy Accelerated – a future focused Australia* (Deloitte, 2018).

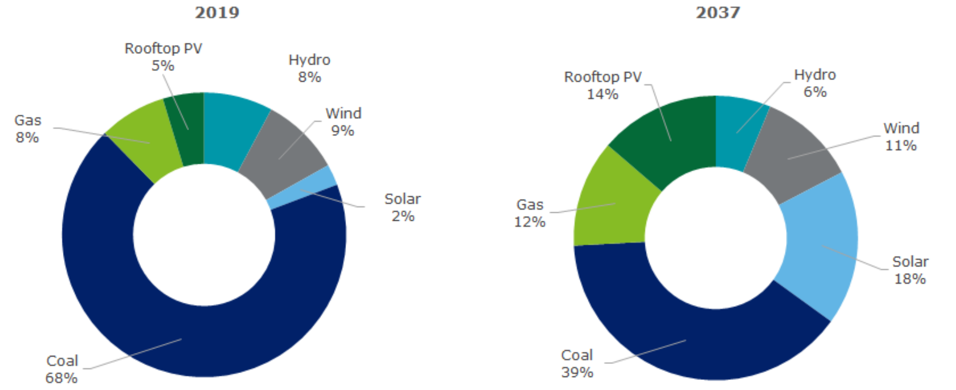
Decentralisation of electricity generation

In addition, a significant increase in rooftop PV is forecast, with the proportion of underlying demand met by rooftop PV expected to nearly triple from 5% currently to 14% in 2037 (AEMO 2018a). This trend is often referred to as 'decentralisation'.

The increasing role of rooftop PV reduces the demand required to be served by investments in the wholesale market ('operational demand'), and therefore, plays a significant role in reducing wholesale prices.

However, there are also challenges to the integration of rooftop PV (and other forms of DER). Targeted investments in distribution networks are critical to ensuring that DER is managed in a way that allows both owners, and the wider network, to benefit from their capabilities.

Forecast change in the generation mix (energy generated) – Base Case



Source: AEMO 2018b; Deloitte

Supporting a least-cost wholesale market transformation

The changing nature and location of electricity generation

Electricity generation is likely to become increasingly distant from load centres, and more geographically dispersed

The transition in the generation mix outlined above will also mean a change in the location of generation.

In its consultation for the Integrated System Plan, AEMO undertook a detailed assessment of energy yields across the NEM to identify areas with the most abundant renewable energy resources, including wind, solar and pumped hydro.

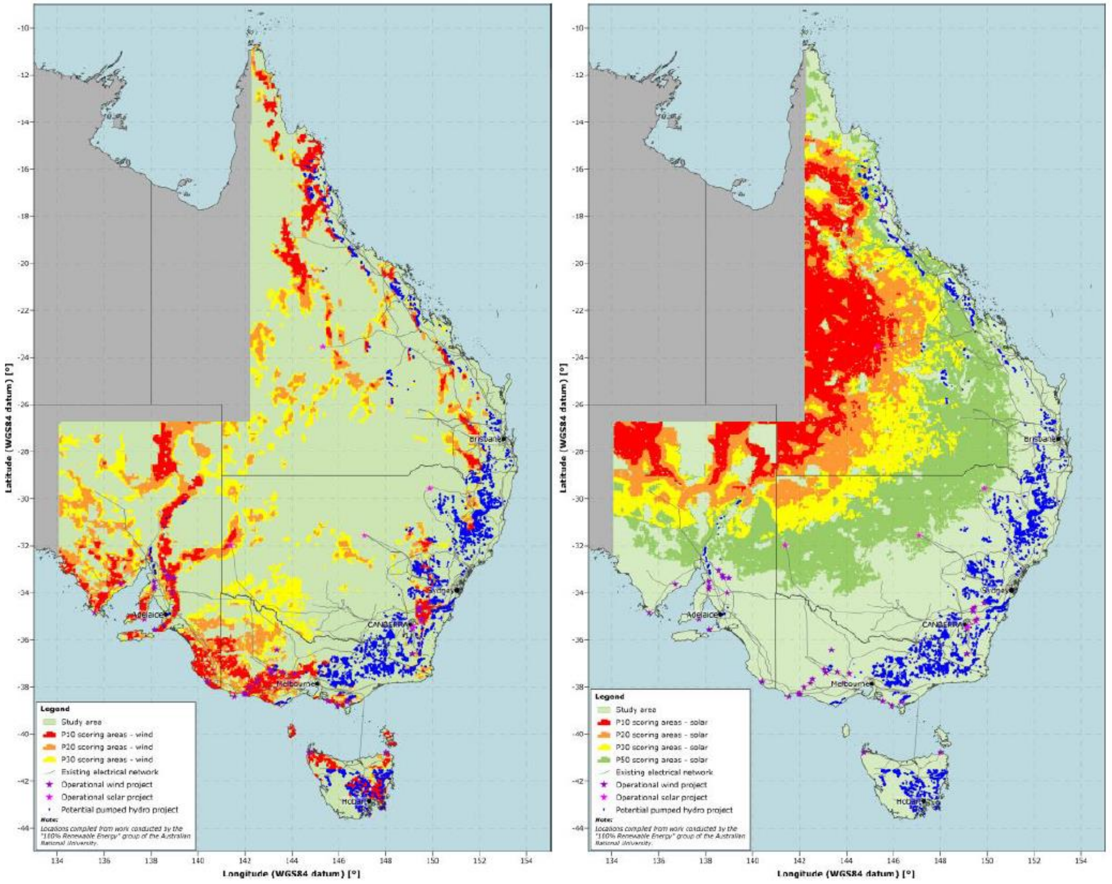
In addition, AEMO considered a number of other criteria, including:

- The diversity of resources – meaning the extent to which a renewable resource (in particular, wind) is available at the same time as other renewable resources. Higher diversity allows greater coordination and efficiency in sharing resources to meet demand
- The extent to which resources are available at the same time as regional demand
- Network limitations, including spare capacity in the existing network, costs of upgrading the network, and loss factors (current and projected under new generation development) (AEMO 2017).

The red areas in the maps to the right indicate highest scoring potential areas of wind (left) and solar (right) generation identified in AEMO's ISP consultation.

Many high scoring sites align well with committed and upcoming renewable generators and transmission development projects already under consideration. However, these sites are typically electrically and geographically distant from major load centres, requiring significant network investment.

Highest potential wind (left) and solar (right) locations – marked in red, orange, yellow and green in order of potential



Source: AEMO 2017

Energy market transformation

AEMO has identified significant benefits from targeted network investments

Integrated System Plan - AEMO

In July 2018, AEMO released its first Integrated System Plan (ISP). The development of the ISP was driven by Recommendation 5.1 in the 2017 Finkel Review. The Finkel Review highlighted the need for planning and decisions about new generation capacity and the development of the transmission network to be made together for efficient development of the system overall (Finkel 2017).

In the ISP, AEMO estimated that spending 8-15% of the total investment required to replace retiring generation capacity on transmission rather than generation will reduce total system costs by between $1.2 and $2.0 billion (NPV), over the next 20 years (AEMO 2018b).

The ISP is designed to assist with decisions on the most optimal path for transmission development, given the potential for trade-offs between factors such as:

- Quality of the generation resource – and in particular, renewable generation resources, such as wind and solar
- Distance from customers and the existing transmission network, and any constraints on access to the transmission network for new (and existing) generators.

Over the long-term, the ISP highlights the importance of developing ‘Renewable Energy Zones’ (REZs) as existing coal generators reach the end of their life. REZs are areas in the NEM where clusters of large scale renewable energy can be developed together.

An example of the use of the renewable energy zone concept is included in the case study to the right, and discussed further on the following page.

Case Study

Texas Competitive Renewable Energy Zone (CREZ)

The Texas Competitive Renewable Energy Zones (CREZs) provides a recent example of the significance of networks in facilitating new large-scale renewable generation. The CREZs enabled significant wind and solar resources, which were located away from major load centres and existing transmission lines, to be developed effectively and efficiently.

The CREZ plan sought to develop new transmission lines to designated renewable energy zones (located away from existing infrastructure and load) in advance of full commitments made from specific wind power projects. Five CREZs were defined and seven transmission/distribution utilities were involved in construction. Risk management strategies included:

- Assessment of financial commitments by renewable generators before transmission utilities are able to begin construction.
- Developing the CREZs in stages – allowing a change of course if needed.

The cost of developing transmission to CREZs was passed on to consumers through the electricity base rate, with prices expected to increase by between $US3-5 per month to cover costs. The project cost US$6.9 billion and has the capacity to transmit 18.5 GW from CREZs in North West Texas to major cities. The project was completed by 2014, and was instrumental in the delivery of an increase in total installed wind capacity from 12.5 GW to 24.8 GW. The project also reduced the proportion of wind energy curtailed from 17.1% in 2009 to 1.2% in 2013, improving the economic viability of renewable energy projects and resulting in reductions in wholesale prices.

Supporting a least-cost wholesale market transformation

Renewable Energy Zones

Renewable Energy Zones (REZs)

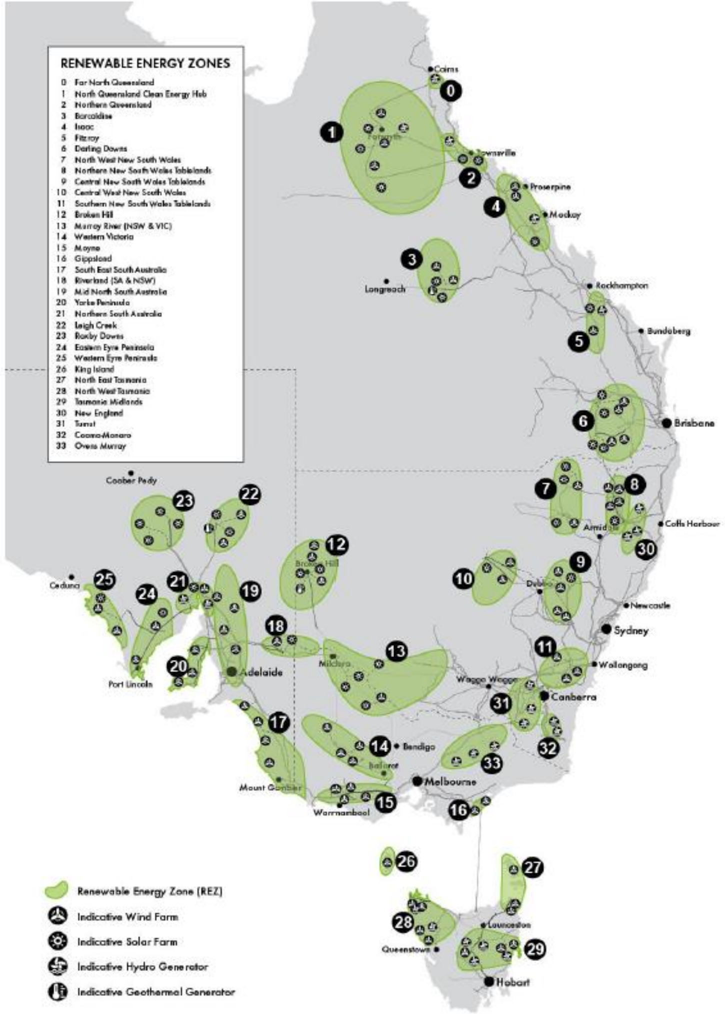
One of the outcomes of AEMO's consultation on the ISP was the identification of 34 potential Renewable Energy Zones (REZs). A REZ is a geographic area where clusters of large scale renewable energy can be developed together, on the basis of suitability as defined by the criteria listed above (e.g. abundant renewable resource, diversity of the resource, network limitations, etc.).

Traditional transmission planning processes have been largely adequate to date. The grid has grown incrementally to occasionally connect a large-scale coal or gas-fired power plant. These plants faces less constraints than wind or solar in terms of location, are typically very large and take a similar amount of time to developer to the time it takes to develop the transmission infrastructure.

On the other hand, wind and solar projects typically face significant locational constraints, are much smaller, and also the timing of construction is significantly shorter (1-2 years) than the time it takes to develop a new transmission line (up to 10 years). The result of this is that decisions about transmission infrastructure development need to be made well in advance of the generation projects.

This results in a challenging situation where generation projects are unable to achieve financial close due to not having confirmed transmission access, and transmission cannot be augmented in the absence of a material need from new projects in an area.

Investments in shared networks (like transmission into REZs) could allow for utility-scale renewables to share the connection/transmission costs – leading more efficient (and potentially higher) deployment of utility-scale renewables (NREL 2017).



Source: AEMO 2018b

Supporting a least-cost wholesale market transformation

Geographic diversity requires targeted network investment

Role of the network and investment needs

The geographic dispersion of new capacity means greater reliance on transmission. Targeted transmission investments able to play a role in delivering the transition at least cost through:

- **Network augmentations** to allow the connection of new, geographically diverse renewable generation and reduce congestion (e.g. as defined in the REZs).
- **Increased interconnection capacity**, to support reliability and security of supply through diversity and defer the need for investments in generation.
- **Non-network solutions**, including enhanced voltage and frequency control, systems that allow for better real-time forecasting, faster scheduling and ancillary services to support growing uptake of small-scale decentralised generation and decreasing operational demand in NEM.

AEMO's ISP identifies $450m-$650m of transmission investment for immediate priority to deliver immediate and long-term benefits, particularly in South Australia.

In the medium term, AEMO has identified a need for further increases in interconnection, including new interconnection between SA-NSW and QLD-NSW (AEMO 2018b).

Summary of transmission investment types

Investment	Description	Benefits
Augmentation	Increases the capacity of the existing transmission network, e.g. establishment of a substation, or construction of new transmission lines.	• Enable more generation to be connected to the network • Improve resilience of loss factors.
Interconnection or reconfiguration	Interconnection between or within regions, or reconfiguration of existing assets to optimise the transmission of electricity. AEMO's ISP includes consideration of a number of interconnection investments, including: • Upgrading the NSW-QLD and the Vic-NSW interconnectors • Increasing SA interconnection • Another Tas-VIC interconnector	• Enable better utilisation of existing resources • More competition within and between regions • Reduce losses • Improve voltage stability and increase reliability, by smoothing out peak demands across regions
Non-Network Solutions	Non-network solutions may include network support from existing and/or new generation or demand side management initiatives (either from individual providers or aggregators) which may reduce, negate or defer the need for network investment solutions. For example, as part of the Power Sydney's Future Project, TransGrid is implementing embedded generation, energy storage and demand response in conjunction with traditional network solutions.	• Decrease costs • Defer and make strategic network investment options • Increase system security by providing ancillary services to support renewable generation • Provide value to consumers by providing market orchestration capability

Sources: AEMO 2018b, Nath & Rana 2011, Transgrid 2018, IPART 2016

Supporting a least-cost wholesale market transformation

Implications of barriers to investment in networks

Implications of barriers to investment in networks

In an investment constrained environment, we would expect to see higher system wide costs to provide reliability and security.

Barriers to investment in transmission are likely to flow through to higher wholesale prices via the following mechanisms:

- **Market entry and competition** – Limitations in the network could result in sub-optimal new entry of generation capacity, as more expensive generation (both gas-powered generation and renewables) is brought on line to replace retiring fleet, and provide additional system support. This barrier to market entry reduces competition in the wholesale market.
- **Diversity of supply** - Investment in network allows better natural resources to participate, thus delaying capacity entry from more expensive sources. The key to a renewables transition is facilitating geographic diversity of resources that complement each other. Reduced investment could lead to barriers to better and more diverse resources.
- **Curtailment and congestion** – as more utility scale renewables enter to replace aging thermal plant closures, constraints in some parts of the network could lead to non-merit order dispatch and the curtailment of some variable renewable generators.

There may also be a range of other costs imposed on the system, which are not necessarily directly observable as increases in wholesale prices, such as:

- Reductions in reliability and security of supply, with a less diverse and flexible generation portfolio available to serve demand across the network
- Increased carbon emissions, to the extent that fossil fuels play a larger role in meeting demand where renewable generation is constrained.

1b. Optimising the use of DER and supporting innovation

Optimising the use of DER and supporting innovation

Moving towards a more decentralised, customer-driven market

Changes in the way consumers use and produce energy

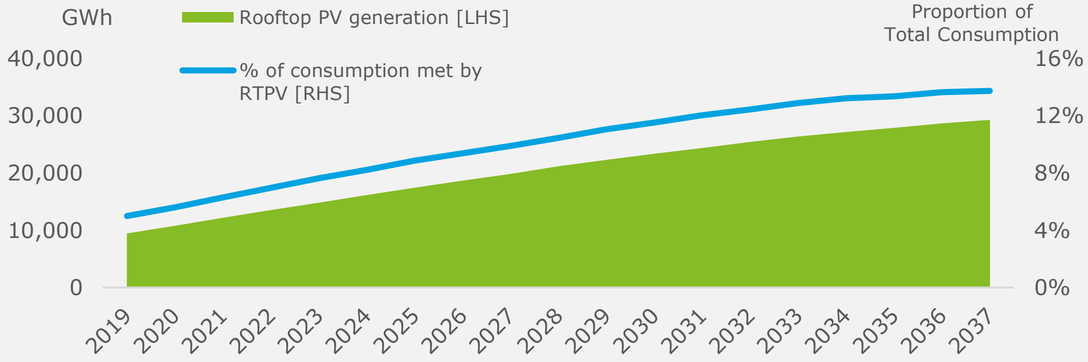
Falling technology costs, high energy prices and a supportive policy environment have seen customers increasingly investing in rooftop PV to exercise greater control over their energy use.

2017-18 was a record year for growth in rooftop PV installations, with about 1,300 MW of new capacity installed (around 260,000 systems), bringing total rooftop PV capacity across the NEM to around 6,500 MW. Nearly a third of all homes in QLD and SA now have solar panels on their rooves, with other States at around 15% penetration.

The output from rooftop PV is now equivalent to around 5% of our total energy consumption needs. Take-up of distributed energy resources (DER) is forecast to continue to increase rapidly over the next 20 years:

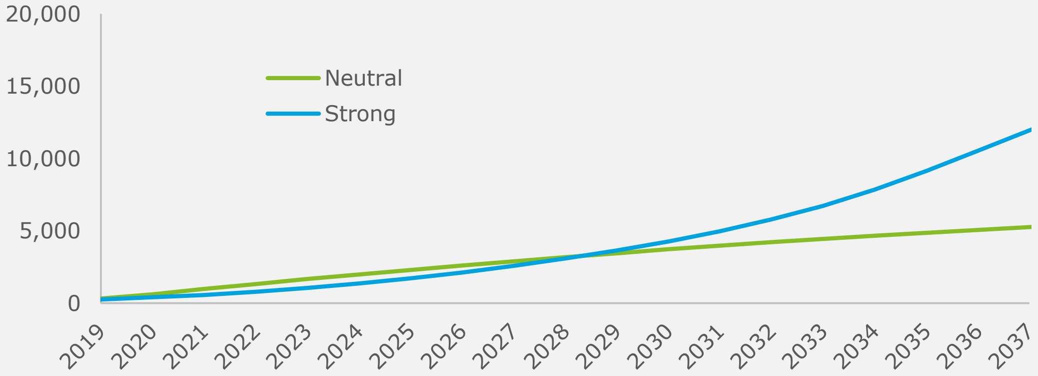
- Rooftop PV is expected to grow from 6.5 GW (2018) to 19.5 GW (2037). The proportion of consumption met by solar in 2037 is expected to reach roughly 14%
- Small-scale Batteries are expected to have a capacity of 2.6 GW across the NEM by 2037, a lower forecast than in previous years because of lower forecast retail electricity prices leading to longer payback periods, as well as tariff structure assumptions
- Electric vehicle uptake is expected to be relatively low over the next decade, with only 650,000 projected to be on the road by 2026. Uptake is expected to accelerate afterwards as EVs become cost-competitive with internal-combustion vehicles. By 2037, 5.5 million electric vehicles could be on the road (AEMO 2018a).

Forecast take-up of rooftop PV (GWh)



Source: AEMO 2018a

Forecast take-up of small-scale batteries (GWh)



Source: AEMO 2018a

Optimising the use of DER and supporting innovation

Previous studies have identified significant benefits from optimising DER

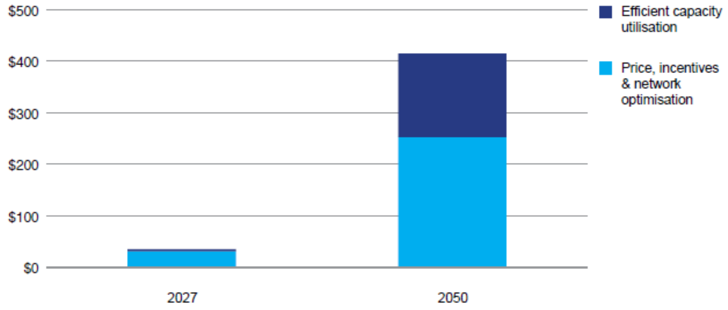
Energy Networks Transformation Roadmap

In its 2017 Energy Networks Transformation Roadmap (ENTR), Energy Networks Australia identified potential savings of around $100bn in total expenditure (across all components of the supply chain) from price and incentive reforms to optimise networks and markets to enable a greater uptake in DER. The ENA estimated that these savings would reduce customer bills by $414 in 2050 (annual saving, $2017), driven by:

- Supported uptake of DER to defer or reduce capacity augmentations and replacement – via efficient pricing structures, incentives and supported uptake and optimisation of DER ($270)
- Efficient capacity utilisation, mainly via managed charging of EVs ($144).

These savings are relative to ENA's counterfactual 'business as usual scenario', characterised by a slow and incomplete adoption of incentives for demand management, no adoption of electric vehicles and ongoing carbon policy uncertainty and the lack of confidence in and coordination of resources (ENA 2017).

ENA estimate of bill savings achievable from network optimisation (annual saving, $2017)



Source: ENA 2017

Open Energy Networks – AEMO and ENA

In light of the benefits identified in the ENTR, AEMO and the ENA have embarked on the Open Energy Networks (OEN) project. The aim of the OEN project is to develop a framework for facilitating the efficient uptake and optimisation of DER, including to:

- Identify the challenges posed by DER to the traditional network model
- Determine how the uptake and use of DER can be supported to maximise the passive (i.e. own consumption) and active (i.e. broader grid) potential of DER
- Establish a framework for optimising the integration of DER (AEMO & ENA 2018).

Optimising the use of DER and supporting innovation

Costs may increase if DER is not managed properly

Network issues may place limits on DER connections and exports

Increased DER, and in particular, exports from rooftop PV and batteries can challenge the stability of the network. High levels of distributed generation raise grid voltage, potentially causing voltage and frequency instability. Typically, this occurs under one or more of the following circumstances

- High levels of DER exports, especially when combined with low demand
- At the edge of the network, low customer density and older infrastructure with lower thermal asset ratings.

To address voltage instability, network responses might include:

- Conservative protection and control settings, such as frequent tap changes on zone substations (transformer output must be kept at a relatively constant voltage. Load tap changers can be installed onto the transformer to raise or lower the voltage)
- Over-specifying network assets to compensate for lack of visibility of DER
- Limiting the export capacity of connections
- Inverter response modes.

Connections and exports may need to be limited

All networks apply limits on how much power can be fed back into the grid by small-scale rooftop PV inverters, depending on the nature of the power supply. These limits currently vary across jurisdictions, and include:

- Requirement for homes with single phase power to install inverters for solar panels with export limits of 5 kW (e.g. Ausgrid, Endeavour, Evoenergy, AusNet Services, Citipower/Powercor, SA Power Networks)
- Limits for three phase power are much higher, typically around 30 kW.

A number of networks are lowering grid voltage to better manage and support the connection of embedded generation. For example, EnergyQueensland has noted that Queensland will transition from 240 volts to 230 volts by late October 2018 (EnergyQueensland, 2018).

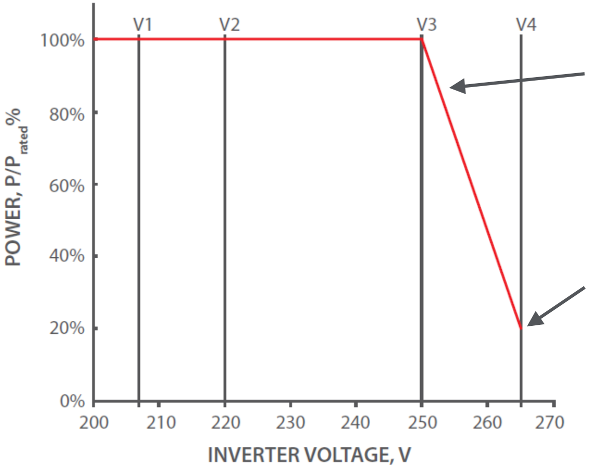
Inverter response modes

Even when applying inverter export limits, networks also need to manage the risk of overvoltage once systems are installed. Inverter responses are defined under the Australian Standards for Solar Inverters (AS 4777). AS 4777 was recently updated to improve response to voltage issues.

Volt-Watt response modes respond to volt changes at inverter terminals by reducing output (i.e., exports) from the system after a certain threshold is met (250V in the figure below), and tripping the system once it exceeds a certain threshold (265V in the figure below).

Inverters must also disconnect from the grid if at any point in time the average voltage exceeds 255V for more than 10 minutes consecutively (AS 4777).

Example curve for a Volt-Watt response mode



At 250V, the inverter starts to reduce system output, linearly down to 20%

At 265V, the inverter trips, cutting all exports

Source: AS 4777.2

Optimising the use of DER and supporting innovation

Limitations and implications for rooftop PV export revenue

Customers with rooftop PV could face limits to their exports

As noted in the previous section, customers with solar panels may face limits on the amount of electricity they can export to the grid via:

- Limits applied to inverters at the time of connection. As noted in section 1, most distribution network service providers require inverters that limit residential single phase connections to exporting no more than 5 kW.
- Inverter response modes applied by distributors to address local voltage issues.

Limiting exports will reduce the amount of revenue received by customers from FiTs. The reduction in revenue will depend on a range of factors, including the prevailing FiT, extent of export limits, patterns of energy use, unit size, and take-up of small scale batteries by customers.

Export limits could significantly impact customer returns from investments in rooftop PV

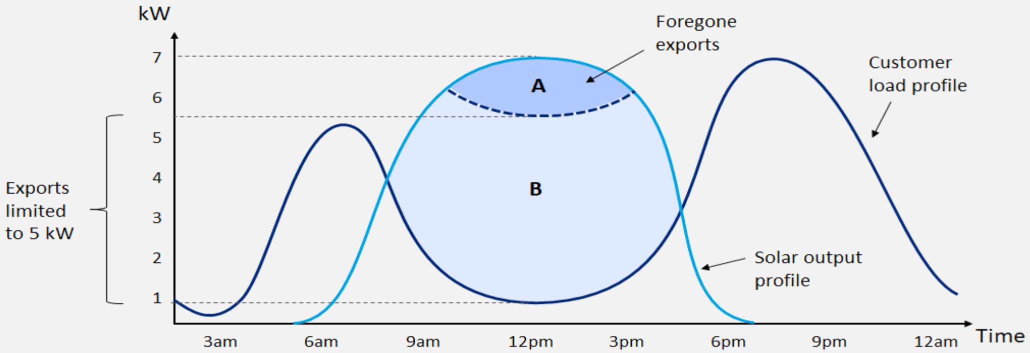
While regulatory benchmarks for FiTs across the NEM currently sit at around 8-10 c/kWh, maximum FiTs offered by retailers are current between 20-25 c/kWh. As such, the FiT revenue at risk for customers whose exports are limited is potentially significant.

For example, based on average energy use and export ratios for a ‘typical customer’ in QLD (as defined by QCA 2017), total annual FiT revenue would be in the order of $460 per annum.

Constraining exports by as much as 20-30% would cost customers in the order of $100 per annum in lost FiT revenue.

Illustration of solar export constraints for a residential customer

The figure below provides an indicative illustration of how an inverter limit might reduce benefits from rooftop solar, for a 7 kW system with a 5 kW export limit.



Source: Deloitte

- The full export potential of the system is the area below the light blue curve (output from the system) and above the dark blue curve (the customer’s energy use); ‘A + B’. Revenue from exports would be ‘(A + B)’ times the FiT.
- A 5 kW limit on the exports would apply whenever the difference between system output and customer load exceeded 5 kW, with the area ‘A’ representing the foregone exports, and foregone export revenue would be ‘A’ times the FiT.
- Note that an even greater share (or all) of the export revenue could be at risk under an inverter response mode that causes the system to trip or reduce exports to address a voltage issue.

Optimising the use of DER and supporting innovation

Role of the network and investment needs

Role of the network and investment needs

As noted above, efficient take-up and use of DER can potentially provide a range of benefits to the network, for example, flattening load and contributing to the optimal use of the network, avoiding augmentation expenditure and pushing back generation capacity investments. However, there may also be costs, particularly around voltage and frequency instability.

To achieve the identified benefits, targeted investment in networks will be required to ensure that the network is ready to manage high levels of DER, and also to ensure that customers can continue to invest and receive benefits.

Proactive management of DER (also know as Market Orchestration (ENA 2017)) requires investments in Advanced Distribution Management Systems (ADMS), which could include a range of investments and actions, such as :

- Enabling various Advanced Network Optimisation functions, starting with basic aggregation and procurement models to more sophisticated markets for services that can be provided by DER, such as **Virtual Power Plants**. ADMS can be utilised to create a virtual power plant to aggregate and orchestrate fleet of distributed energy resources. A 5 MW Virtual Power Plant is currently being trialled in South Australia that has improved network stability, support of renewable generation and reduced energy bills for consumers. The three-year trial will give South Australia Power Networks (SAPN) greater visibility into behind-the-meter battery storage. SAPN will also be able to use the batteries as DERs that can address local network constraints and manage demand.
- **Managed charging and discharging** of batteries and electric vehicles (smoothing demand peaks), supported by cost reflective tariffs that signal the broader costs of coincident demand
- Enabling bi-directional flows and **reactive power injection**. As many generation units are connected to the grid via power electronic converters, their reactive power feed-in can be controlled independently from their active power feed-in.
- **Voltage monitoring and voltage regulation.** These measures include:
  - Remote switches and embedded sensors throughout the network measuring parameters such as voltage, frequency and power quality
  - Remote tap changing
  - Capacitor banks, voltage regulators and remote static VAR compensators (for fast acting reactive power)
  - Advanced inverters that can more effectively maintain system stability in high DER scenarios and distribution circuits – which are installed in transformers and throughout low voltage networks.
  - In addition to load management, demand side management (DSM) can also assist in resolving voltage fluctuations (in addition to thermal limit issues), by adapting the load profile, in conjunction with the customers on the network.

Many of these options will also require power quality data from advanced metering data providers.

While these investments have the potential to reduce costs in the long-run, we note that many will require upfront spending, and will not necessarily be directly aligned with networks' regulated functions and service obligations as defined in the National Electricity Rules (NER). For example, there is no regulatory requirement upon the businesses to facilitate, or attempt to maximise, customers' ability to export electricity.

The scale of investment required to connect rooftop PV, facilitate bi-directional flows and maintain a secure supply will vary by jurisdiction.

Optimising the use of DER and supporting innovation

Implications of barriers to investment in networks

Implications of barriers to investment in networks

Barriers to investments in distribution networks could result in:

- **Underutilised distributed generation** – rooftop PV or batteries unable to feed into the grid directly increases the amount of energy consumption needed to be met with large scale generation and network investments, increasing system-wide costs relative to a scenario where rooftop PV is able to operate to its full capacity. Ultimately, we would expect this to result in lower take-up of DER
- **Increased peak loads and requirement for traditional network augmentations –** without investment in appropriate market orchestration ADMS and capabilities, in order to manage the increasing reverse power flows on the grid, uncoordinated charging of EVs and batteries, networks will need to invest in conventional network upgrade to increase DER hosting capacity.
- **Direct impacts on customer bills from lost FiT revenue –** if customers are unable to feed electricity back into the grid, they will face a direct cost due to the portion of the electricity generated by their system is neither used nor paid for. Initial estimates suggest this cost could be in the order of several hundred dollars per customer (depending on system size, the solar resource, feed in tariffs and customer usage patterns and also whether customers have battery-support)
- **Rely on FCAS Services through traditional power stations –** a virtual power plant enabled through ADMS can provide ancillary services to respond to imbalances created by renewable energy and other variable resources, or failures of large power plants. Without the virtual power plant, networks will have to rely on traditional coal/fossil fuel power plants for supply balancing and responding to contingent events. The costs of this service are borne by consumers and market participants.
- **Quality and reliability of supply –** Lack of automated voltage regulation and power factor correction to maintain voltages within target ranges will result in a weak (non-reliable) supply to end users and businesses with growing embedded generation within the network. Without a reliable supply, customers will be limited in usage of new technologies such as electric vehicles, rooftop PV with smart energy management systems and sophisticated electronic devices which require a stable power supply.

2. Energy market impacts

Scenario analysis and results

Energy market impacts
Overview

Introduction

In this section, we assess the impact on the energy sector from an underinvestment in network infrastructure.

To perform our analysis, we have defined two alternative scenarios for the transformation of the energy market:

- Base Case – energy market transformation progresses with efficient network investment being an integral part of the energy market transition
- Network Underinvestment scenario – barriers to investment in networks impede the connection of a least-cost generation portfolio and optimal take-up and use of DER.

This section is structured as follows:

- Overview of the Deloitte Energy Market Model (DEMM)
- Description of our Base Case and Network Underinvestment scenario
- Results:
  - Investment in generation
  - Wholesale price outcomes
  - Network investment assumptions
  - Retail price outcomes
  - Carbon emissions.

Energy market impacts

Deloitte Energy Market Model

Overview of the DEMM

Our analysis is underpinned by the Deloitte Electricity Market Model (DEMM) The DEMM is built using PLEXOS, a leading electricity market simulation software.

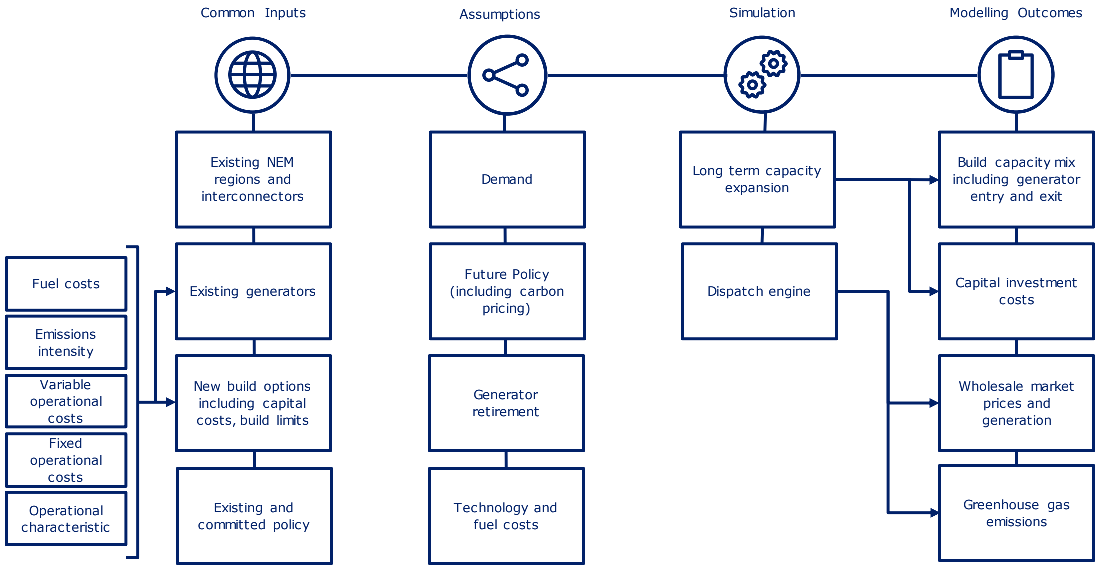
The DEMM simulates generator behaviour and market outcomes in the NEM. It is based on an extensive database containing all of the existing generators in the market, and potential new entrants.

It takes into account a range of parameters, including profit maximisation by generators, demand side behaviour from residential and commercial customers (including demand management), impact of Government policy, large and small scale energy storage, and stochastic outcomes such as random generator outages.

Broadly, the DEMM is structured around two complementary modules: Long-term capacity optimisation and dispatch simulation.

- The **Long-term capacity optimisation module** optimises entry and retirement of generation capacity to meet demand at least-cost over the long-term.
- The **Dispatch simulation module** simulates detailed chronological dispatch. It can provide market outcomes at very granular levels, but is typically modelled in 30 minute or hourly steps. It simulates strategic behaviour from generators and companies to profit maximise portfolios, including contract positions.

DEMM modelling architecture



Common Inputs

Existing NEM regions and interconnectors

Existing generators

New build options including capital costs, build limits

Existing and committed policy

Fuel costs

Emissions intensity

Variable operational costs

Fixed operational costs

Operational characteristic

Assumptions

Demand

Future Policy (including carbon pricing)

Generator retirement

Technology and fuel costs

Simulation

Long term capacity expansion

Dispatch engine

Modelling Outcomes

Build capacity mix including generator entry and exit

Capital investment costs

Wholesale market prices and generation

Greenhouse gas emissions

Energy market impacts

Base Case and Network Underinvestment scenario

Base case

Our Base Case reflects our current forecast of the NEM, with all existing and committed generators and policy.

Inputs for the Base Case are derived from our standard modelling assumptions, updated for the AEMO 2018 ISP Neutral Scenario, released in July. These include:

- **Technology costs –** underlying costs of different generation technologies
- **Underlying demand –** total electricity demand, including demand met by rooftop PV
- **Policy settings –** all current policies remain in place (e.g. the RET, SRES and VRET).

Modelling results are produced by NEM region and aggregated for the entire NEM.

Network Underinvestment scenario

In our Network Underinvestment scenario, we:

- Reduced distribution expenditure consistent with estimates of investment required to facilitate and optimise the update of DER – amounting to around a 15% per year reduction in capital expenditure. We assume this reduces both the take-up of, and exports from, rooftop PV (i.e., a shift from AEMO's neutral to weak rooftop PV forecast).
- Reduced transmission expenditure in accordance with certain capacity augmentations identified in AEMO's Integrated System Plan, which limits the amount of generation that can be built in key areas
- Applied an annual growth figure to future network expenditure, consistent with the ENA's estimates of network savings achievable from targeted network investments (which we assume are foregone).

The majority of modelling inputs from our Base Case remain unchanged in our Network Underinvestment scenario. These include technology costs, underlying demand and policy settings.

Impacts of underinvestment in networks were considered via two pathways:

- Limitations on the connection of new utility-scale renewable generation
- Limitations on the amount of energy that can be fed into the grid from rooftop solar, and consequential reductions in the take-up of rooftop PV.

Utility scale connections were limited by identifying regions where there are currently limits on the capacity of the network to support additional generation capacity, and putting maximum build limits on these areas to reflect our counterfactual scenario where the required network investment does not go ahead.

These are typically areas where the renewable resource (wind or sun) is strongest and provides the highest capacity factor for new builds. This limits both the available connection points to the NEM, and also the number and diversity of renewable energy resources that can be brought to market.

Rooftop PV was limited by:

- Adjusting rooftop PV output downwards to reflect restrictions in the amount of energy that can be fed back into the grid during the middle of the day
- Reducing the overall take-up of rooftop PV in each region, to reflect barriers to connections (network limitations) and customer response to reductions in feed-in revenue. This reduction was based on a shift from AEMO's Neutral to Weak take-up of DER.

Energy market impacts

Results – changes in the generation mix

Underinvestment in networks results in a greater reliance on existing fossil-fuelled generation

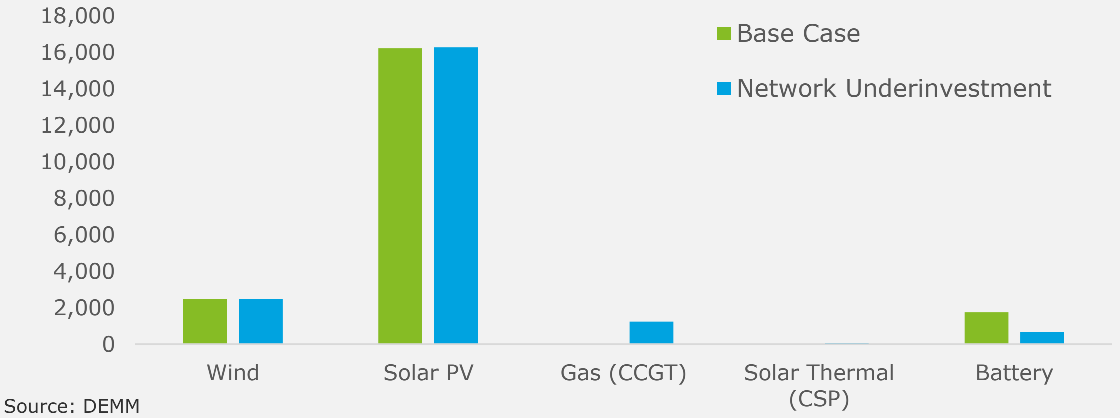
Headline new entry and generation investment figures are similar between the two scenarios. Over the next 20 years, both scenarios add around 20GW of generation capacity to the market, at a cost of around $25bn.

There are some minor differences in the type of generation constructed. The Network Underinvestment scenario includes some new gas capacity, plus a very small amount of Concentrating Solar Power, while the Base Case relies more on utility scale batteries.

However, there are also some important differences:

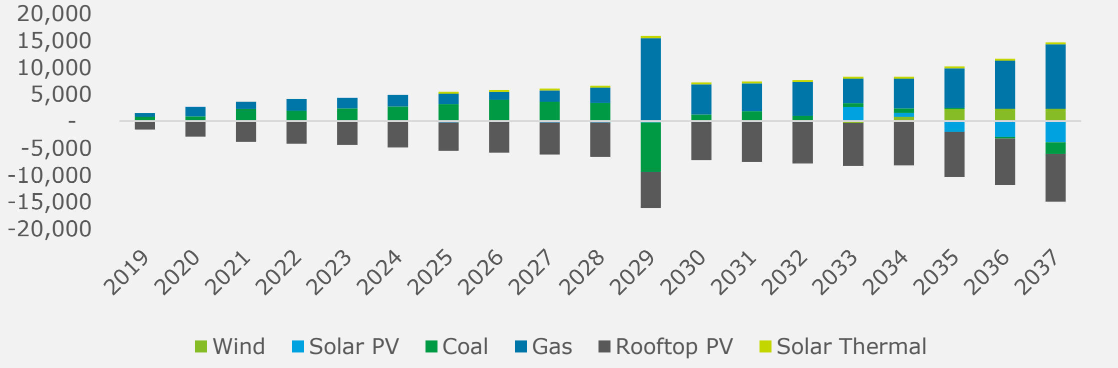
- **Generation output (fuel mix)** differs substantially between the two scenarios. The Network Underinvestment scenario has lower generation from rooftop PV than the Base Case, which is replaced mainly by existing coal and gas generation.
- **The location of new renewable energy plant** differs significantly, as a result of the build limits in areas where there are existing capacity constraints in the transmission network. The implications of these constraints for the location of new generation build are discussed on the following slide.

Total new build to 2037, MW



Source: DEMM

Change in fuel mix in the Network Underinvestment scenario relative to base case, GWh



Source: DEMM

Energy market impacts

Results – changes in the location of new generation

Constraints in network capacity can hinder the development of the most valuable renewable energy resources

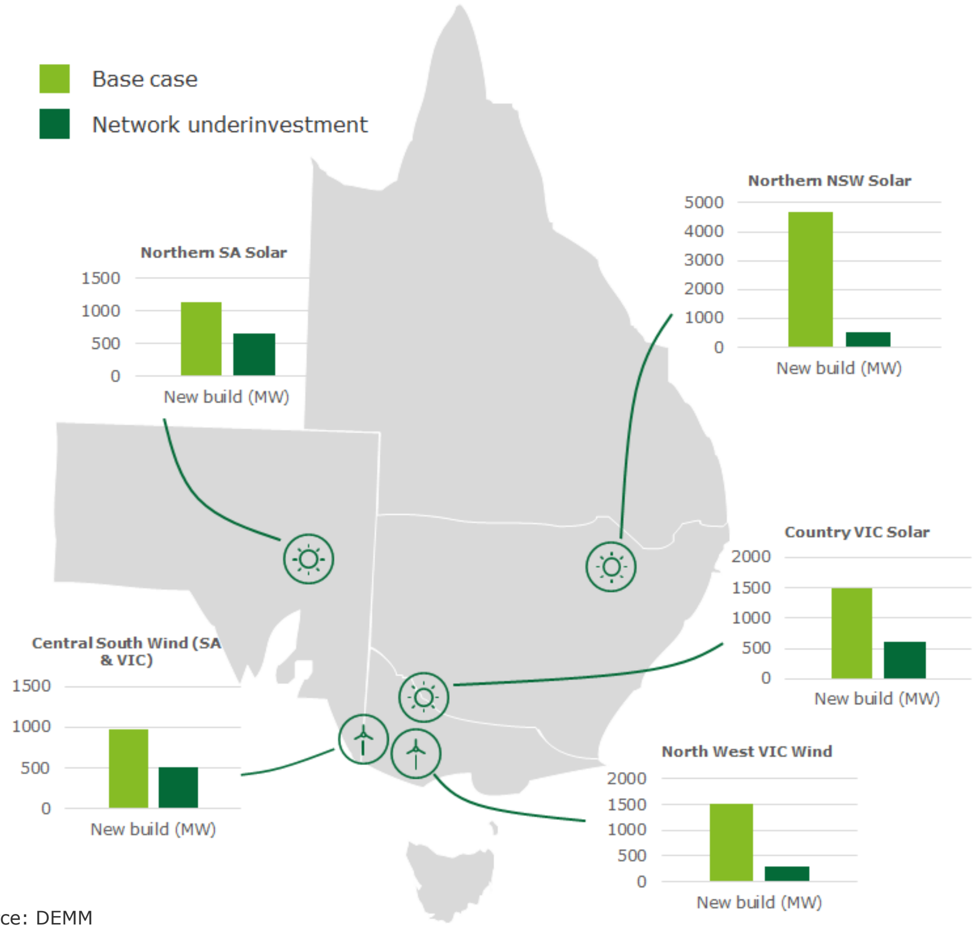
Investment in the network is crucial to developing the most valuable renewable energy resources to meet demand. The value of a renewable energy resource can be defined by:

- **Resource quality –** areas with high levels of solar radiance or high wind speeds are likely to deliver the highest 'bang for buck' in terms of generation output for a given investment in capacity
- **Diversity –** diversity of renewable generation output allows more demand to be met across the day.

As shown in the figure on the right, in the Network Underinvestment scenario, access to some of the most valuable renewable energy resources is restricted due to limitations on capacity in the network. For example:

- Northern NSW has been identified by AEMO as having abundant solar resources with potential for at least 5 GW of solar generation capacity (AEMO 2018b), but could be limited to only another 525MW without significant investment.
- In SA, constraints in the network in the North of the State reduce the amount of solar that can be brought on by over 1,000 MW, while constraints in the windy South East of the State reduce the new wind amount by half.
- Western Victoria has strong wind resources, but without further network augmentation could be constrained from adding more than around 300 MW of additional wind capacity.
- In QLD, while there are constraints in the northern part of the State, these have a limited impact on either scenario, as the distance from load makes this area less attractive as a location for generation than South East Queensland and other locations in the NEM.

Geographic location of major constraints on new builds to 2037



Source: DEMM

Energy market impacts
Results – wholesale price outcomes

Wholesale prices are higher in the Network Underinvestment scenario

Prices in the Network Underinvestment scenario are, on average, around 7% higher than prices in the Base Case. These results emphasise the importance of targeted network investment in both transmission and distribution infrastructure in delivering a least-cost pathway

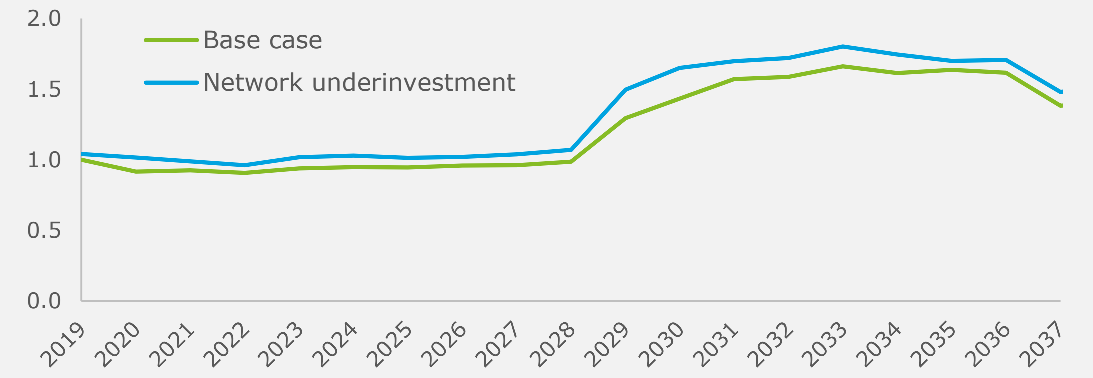
This price differential is primarily driven by:

- Lower rooftop PV output, due to underinvestment in the distribution networks, necessitating increased generation from the wholesale market – mainly from gas and coal
- Constraints in the location of some new entry of generation capacity, with less valuable renewable energy resources needing to be developed to meet demand.

Rooftop PV provides a natural hedge against retirement of existing generation

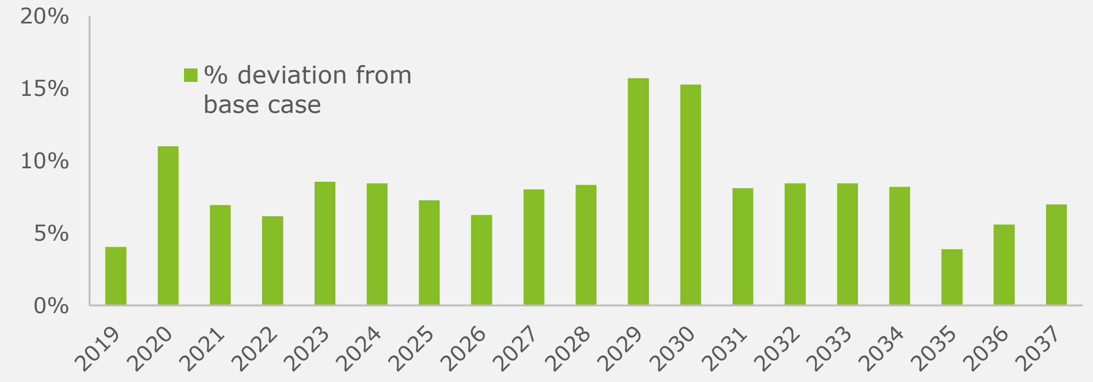
- In both scenarios we see an increase in prices over 2029-30 due to retirement of existing coal plant (Vales Point and Gladstone)
- The price increase is the results of a step change in the merit order after the retirement of coal – which is replaced by a combination of gas and renewables.
- The actual timing and extent of this step change will depend on a number of factors, including timing of retirements, the level of demand and availability of replacement sources of generation.
- In the base case, the price increase is both delayed, and slightly mitigated, relative to the Network Underinvestment scenario. This is primarily due to higher levels of rooftop PV reducing operational demand, which reduces the amount of gas that enters the generation mix to replace coal.

Wholesale price forecast, index



Source: DEMM.

Network underinvestment scenario, % change in wholesale prices from base case



Source: DEMM.

Energy market impacts

Results – network investment assumptions

Network investment assumptions

In the Network Underinvestment Scenario, we assume that networks are constrained in their ability to continue to invest in supporting the efficient adoption of small and large-scale energy resources.

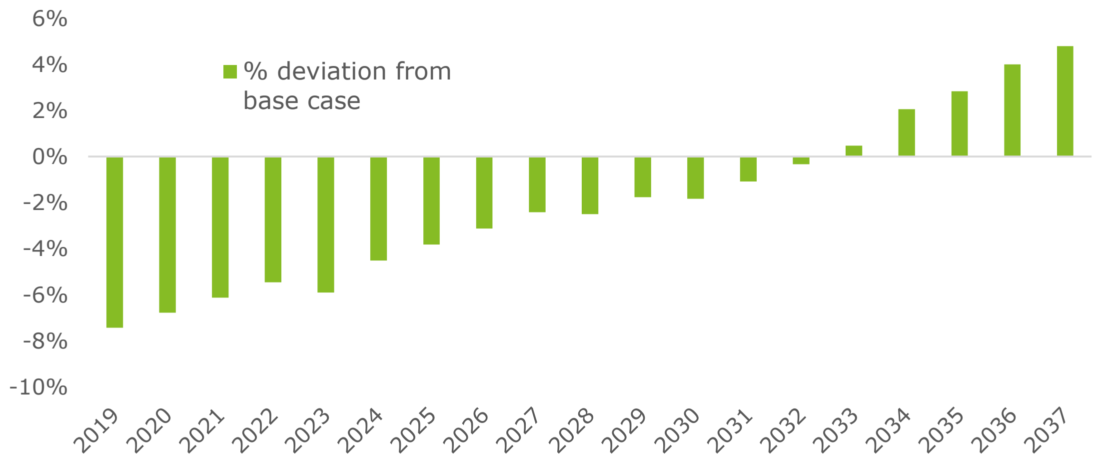
Note that we have not considered the implications for operating expenditure in the Network Underinvestment scenario, however, we note that over the longer-term we would expect operating expenditure to be higher in our Network Underinvestment scenario, given higher reliance on traditional network augmentation expenditure.

Our core assumptions are as follows:

Distribution network investments are limited to those required to meet regulatory obligations

- Distribution businesses are restricted to investing in items related to mandatory licence conditions, regulatory requirements, and risk-based repairs and replacements (i.e. a passive or traditional approach to investment, rather than proactive or dynamic).
- While this results in a short-term reduction in costs, over time investment requirements increase due to increased need for traditional augmentations to the network to meet capacity requirements.
- This outcome is consistent with information obtained from our consultations with network businesses and analysis undertaken by ENA and the CSIRO in their Energy Networks Transformation Roadmap. The ENA and CSIRO found that by 2050, expenditure on the distribution networks could be up to 22% higher under a traditional 'poles and wires' augmentation, rather than dynamic, approach to network investment (ENA 2017). In line with the findings of the ENA and CSIRO, we assume that a dynamic approach to investments in technologies and systems for local network orchestration will ultimately reduce the need to expand the capacity of the network.

Network underinvestment scenario, % change in network investment from base case



Source: Deloitte analysis, based on regulatory submissions, consultations with network businesses, and ENA 2017

Transmission network investments are delayed

- A number of transmission investments required to connect new renewable generation capacity to the NEM are delayed. Costs associated with these investments are based on figures in AEMO's 2018 ISP, and are removed from our forecast.
- Similarly to the case for distribution, the ENA and CSIRO found that transmission network expenditure could be around 21% higher in 2050 where DER is not optimally coordinated or integrated (ENA 2017). Therefore, we assume an upward trajectory for transmission expenditure in line with this figure.

Energy market impacts

Results – retail market outcomes

Retail prices initially fall, but increase over time as a result of underinvestment in electricity networks

Reduced investment in the networks initially puts downward pressure on prices, but over time, higher wholesale costs and an upward trend in network costs result in higher retail prices in the Network Underinvestment scenario.

The combined impact on retail prices of the movements in wholesale prices and network costs was calculated based on the relative proportion that each of these components makes up of the average customer bill (as set out in ACCC 2018).

The change in retail prices is driven by:

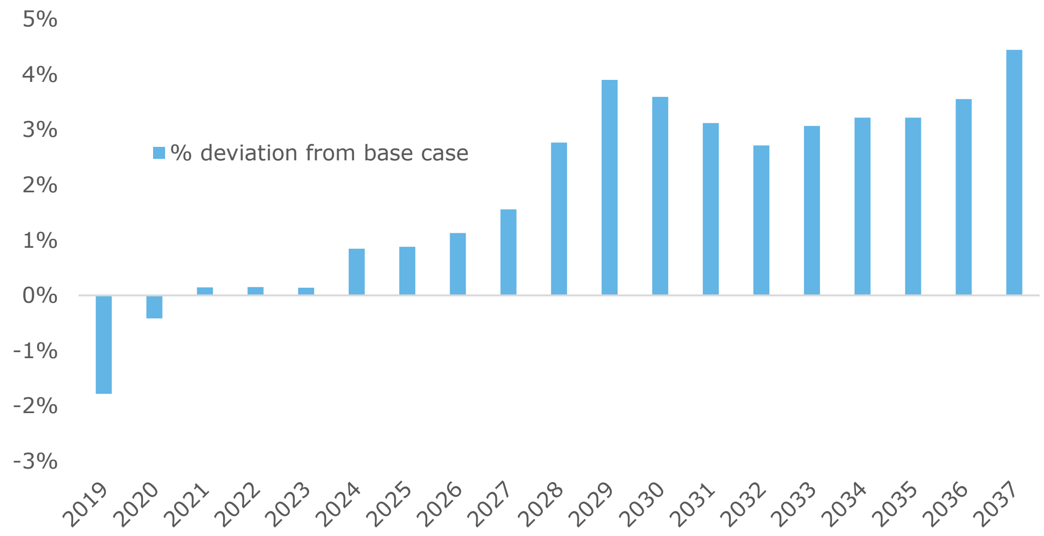
- **Changes in wholesale prices –** wholesale prices are consistently around 7% higher over the forecast period in our Network Underinvestment scenario
- **Changes in network costs –** network costs are lower over the next decade, but then rise steadily to reflect increased needs for augmentation expenditure.

These factors initially result in a reduction on retail prices as the network cost effect dominates, then broadly cancel each other over the first 5 years of the forecast, after which the net result is a persistent increase in costs to customers.

These are aggregate results across the NEM, and do not take into consideration changes in patterns of energy use or tariff structures. These and other factors are assumed to be the same in the Base Case and Network Underinvestment scenario (such as the costs of national and State-based environmental policies).

Where optimal investment **does** go ahead in the networks (as represented in our base case), we would see a reduction in the total retail bill, despite an initial increase in network costs reflecting targeted network investment to facilitate the energy transformation. Therefore, in our base case, we would expect lower retailer prices than in the underinvestment case, with the difference in prices increasing over time.

Network underinvestment scenario, % change in retail prices relative to base case



Source: DEMM, Deloitte analysis, based on average retail bills as set out in ACCC 2018

Energy market impacts
Results – carbon emissions

Impact on carbon emissions

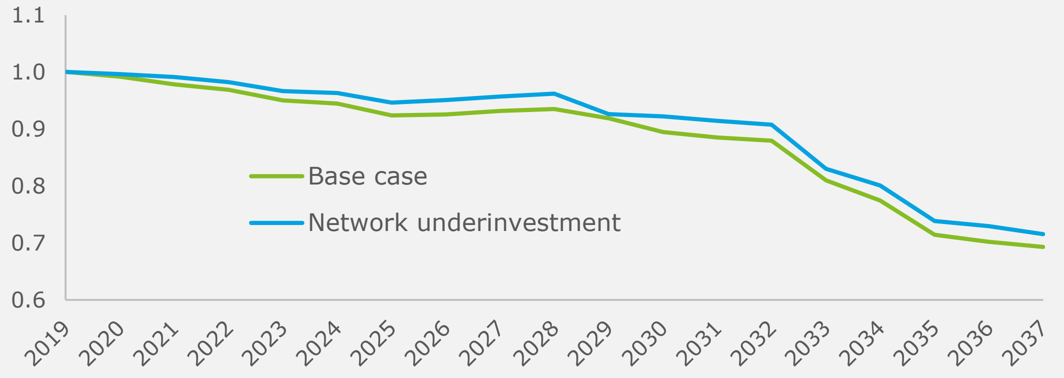
Both scenarios exhibit a downward trajectory for emissions, as retiring existing coal-fired generation is replaced by renewable generation.

Over the forecast period, in the Network Underinvestment scenario we see a cumulative increase in emissions of 70.6 Mt CO2-e, relative to the base case. This is driven primarily by:

- Greater uptake and use of rooftop PV in the Base Case
- Higher use of gas in the Network Underinvestment case.

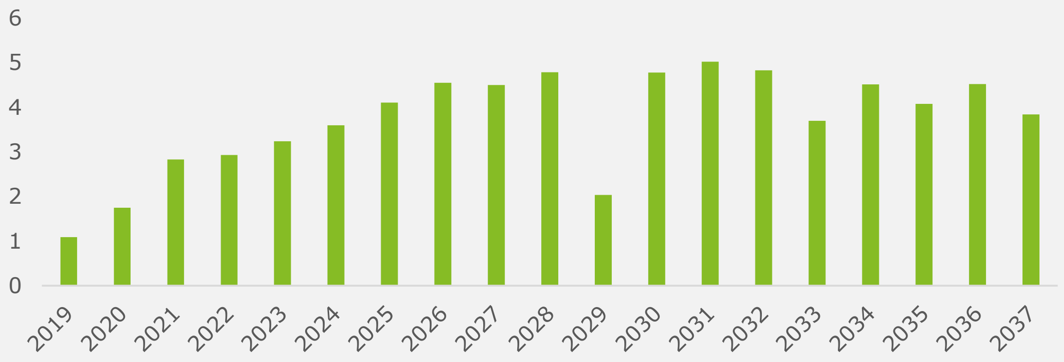
The interaction between emission reductions and price are becoming increasingly complex, as technology costs continue to fall and the nature of the wholesale market changes. However, this study illustrates that over the longer term, lower prices can be delivered in conjunction with higher emissions reductions, subject to targeted and efficient investment in the electricity networks.

Annual electricity sector emissions, index



Source: DEMM.

Increase in annual electricity sector emissions in the network underinvestment scenario relative to base case, Mt CO2-e



Source: DEMM.

3. Economic impacts

Scenario analysis and results

Role of networks in supporting economic growth

Overview and modelling approach

Linking energy market outcomes to the broader economy

In this section, we explore the connection between the energy market and economic outcomes.

Energy is a critical input to economic activity, with every $1 of GDP requiring on average 3.58 megajoules of energy.

Electricity is one of the most significant sources of energy consumed in Australia, accounting for around 20% of total final energy consumption, behind petrol (49.3%) and natural gas (21.4%).

Electricity plays an important role in powering industry, medium and small businesses and households and is likely to become more important in powering transportation in the future.

It follows that a limit on investment in electricity infrastructure (relative to the base case) that increases the price of electricity will result in a contraction in the Australian economy. Further, a reduction in investment in energy infrastructure will have a negative impact on economic output and employment.

Overview of modelling approach

We have applied Deloitte Access Economics' computable general equilibrium model (DAE-RGEM) to measure the implications of the alternative energy market scenarios outlined in this report.

DAE-RGEM is a large scale, dynamic, multi-region, multi-commodity computable general equilibrium (CGE) model of the world economy with bottom up modelling of Australian regions.

DAE-RGEM encompasses all economic activity – including production, consumption, employment, taxes and trade – and the inter-linkages between them.

In this instance, we will explore the impacts on the following key economic indicators:

- Gross State Product (GSP) – by State and for the NEM as a whole
- Employment – for the NEM region as a whole
- Industry output – key industries likely to impacted by the results

Modelling inputs – energy market outcomes

The energy market outcomes provide the basis for the 'shocks' to be applied in the Network Underinvestment scenario in DAE-RGEM:

- **Change in retail electricity price:** an increase in retail electricity price will reduce the GSP forecast relative to the base case. Employment will also decline. Some sectors of the economy will be hit harder than others depending on their energy intensity. For example, the aluminium sector will contract under a scenario with high electricity prices, but there will only be minimal impact on the service sectors.
  Change in retail electricity price is determined with reference to the retail cost stack. That is, the retail electricity price is varied by the percentage increase in the various components of the retail bill, with aspects that are not impacted (i.e. environmental policy costs) unchanged.
- **Change in network investment:** a decline in network investment (relative to the base case) will have a further impact on GSP and employment outlook.

Role of networks in supporting economic growth

Results – impact on gross state product

GSP outcomes are lower in the Network Underinvestment scenario

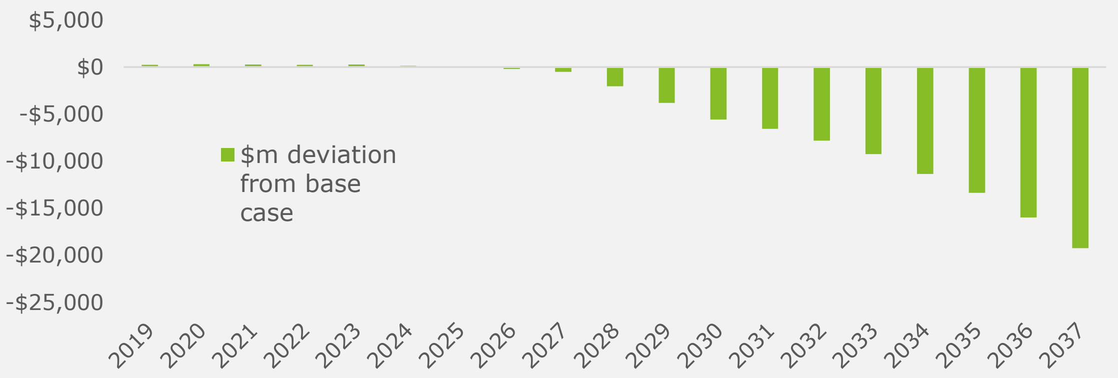
Over the next 10 years, the impacts on the broader economy are subdued, with little change from the Base Case. This reflects the relatively minor change in retail prices over this time.

However, post 2027, as price increases start to accelerate, we see more significant impacts on the economy.

The cumulative reduction in GSP across the NEM States by 2030 is over $10 billion, and by the end of our forecast period (2037), the cumulative reduction in GSP across the NEM is over $90 billion.

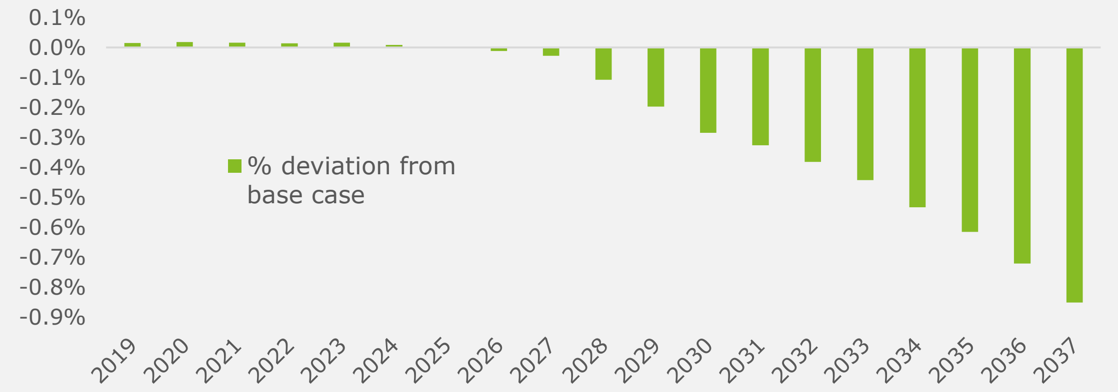
There is some minor variation in results between States, reflecting both exposure to electricity prices through industry make-up, and also the size and complexity of the economy – and therefore ability to absorb economic shocks.

Change in GSP in NEM States in Network Underinvestment scenario ($m)



Source: DAE-RGEM.

Change in GSP in NEM States in Network Underinvestment scenario (%)



Source: DEMM.

Role of networks in supporting economic growth

Results – impact on gross state product

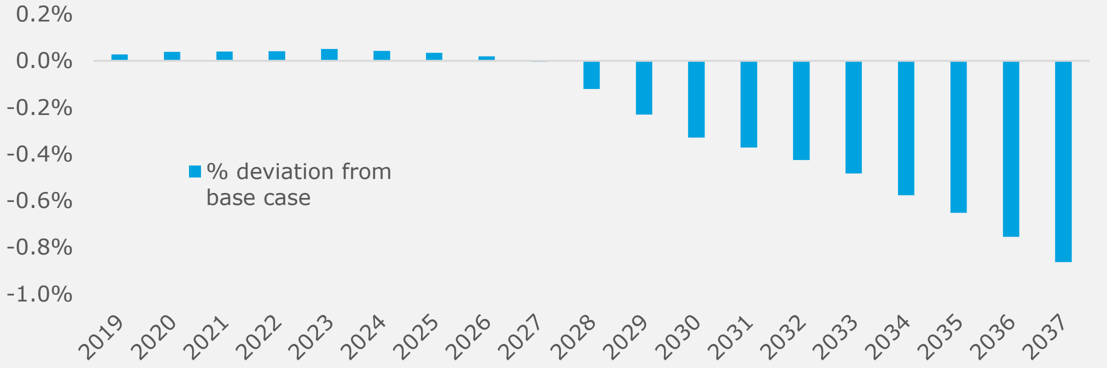
Employment is initially steady, but falls significantly relative to the base case post 2027

The initial downward step in electricity prices in the first decade of the Network Underinvestment scenario results in a slight increase in employment across the NEM. In Victoria, where the initial price drop is slightly larger than in other States, employment peaks in 2027 at around 6,000 FTE (0.2%) higher than in the base case.

By 2030, employment is 40,329 FTE lower across the NEM States (0.9%), including:

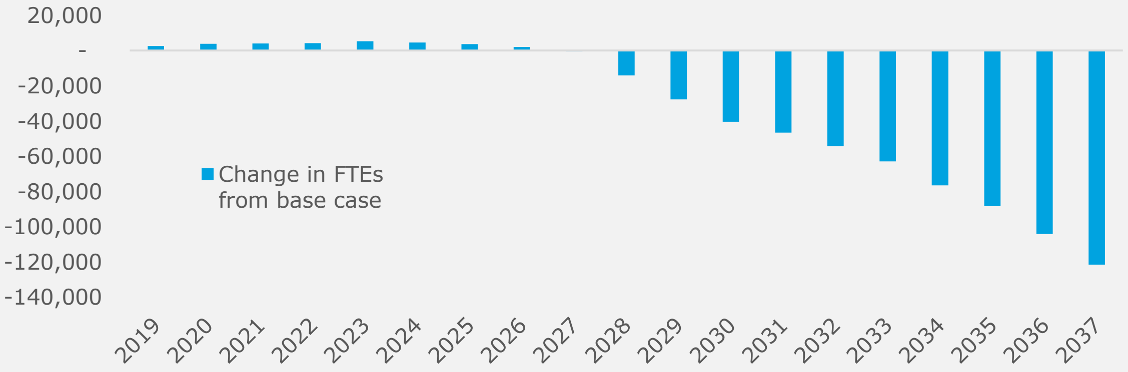
- 17,979 FTE lower in New South Wales
- 7,861 FTE lower in Victoria
- 6,975 FTE lower in Queensland
- 4,149 FTE lower in South Australia
- 3,365 lower in Tasmania.

Change in employment in NEM States in Network Underinvestment scenario (%)



Source: DAE-RGEM.

Change in employment in NEM States in Network Underinvestment scenario (FTE)



Source: DAE-RGEM.

Role of networks in supporting economic growth

Results – impact on gross state product

Most industries experience a contraction in output as a result of electricity price rises in the Network Underinvestment scenario

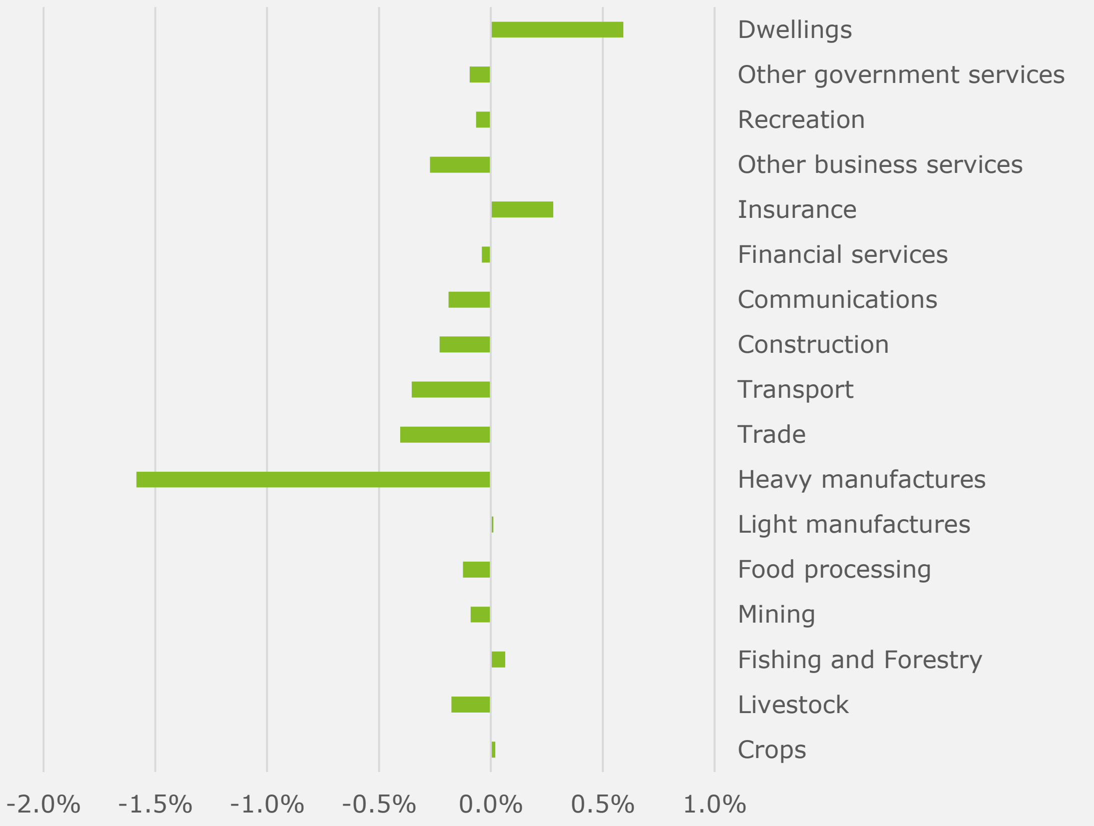
Most industries use electricity as an input to some degree. Accordingly, the increase in retail electricity prices in the Network Underinvestment scenario results in slight contraction in most industries.

The industries affected most are:

- Heavy manufacturing (-1.6% to output)
- Trade (-0.4%)
- Transport (-0.4%).

Conversely, a slight increase in output is experienced in the Dwellings (0.6% increase in output) and Insurance (0.3% increase) – these being sectors with relatively minor exposure to electricity prices.

Change in industry output in the Network Underinvestment scenario as at 2037 (%)



Source: DAE-RGEM.

Appendices

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