Jemena Electricity Networks (Vic) Ltd

JEN – RIN – Support – Consumer Energy Resources – Integration Strategy

Attachment 03-01

Table of contents

List of tables

Abbreviations

3D	Three dimensional
AAA	Australian Automobile Association
ACCC	Australian Competition and Consumer Commission
ADMS	Advanced Distribution Management System
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
AMI	Advanced Metering Infrastructure
APVI	Australian PV Institute
CER	Consumer Energy Resources
CSIP-Aus	Common Smart Inverter Profile, based on IEEE 2030.5 applicable to Australia
DCCEEW	Department of Climate Change, Energy, the Environment, Water
DEECA	Department of Environment, Energy and Climate Action
DER	Distributed Energy Resources
DERMS	Distributed Energy Resource Management System
DNSP	Distribution Network Service Provider
DOE	Dynamic Operating Envelope
DPV	Distributed Solar PV
DVM	Dynamic Voltage Management
EDCoP	Electricity Distribution Code of Practice
ESB	Energy Security Board
ESOO	Electricity Statement of Opportunities
EV	Electric Vehicle
GIS	Geographical Information System
GWh	Giga Watt hour
HV	High Voltage
HVAC	Heating, Ventilation and Air Conditioning
IASR	Inputs, Assumptions and Scenarios Report
ICT	Information and Communications Technology
IoT	Internet of Things
JEN	Jemena Electricity Networks (Vic) Ltd
kVA	Kilo Volt - Ampere
LDC	Line Drop Compensation
LiDAR	Light Detection and Ranging
LV	Low Voltage

MW	Mega Watt
TWh	Terra Watt-hour
NEM	National Electricity Market
NER	National Electricity Rules
NPV	Net Present Value
PQ	Power Quality
PV	Photovoltaic
SCADA	Supervisory Control and Data Acquisition
TNSP	Transmission Network Service Provider
UFLS	Under Frequency Load Shedding
UNFCCC	United Nations Framework Convention on Climate Change
V2G	Vehicle to Grid
VPP	Virtual Power Plant
VVC	Volt-VAr Control

Overview

As an electricity Distribution Network Service Provider (**DNSP**) operating in Victoria, Jemena Electricity Networks (Vic) Ltd. (**JEN**) plays a key role in facilitating the energy market transformation to renewable energy. Given the uncertainty in the rate of change and direction of the transformation, a least-regrets scenario-based investment approach is needed to manage a smooth transition for customers. Furthermore, Jemena has its own ambitions to work towards net zero[1]. We have therefore developed this Consumer Energy Resources (**CER**) Integration Strategy and associated programs of work and initiatives to support the energy transition over the next decade.

Energy market transition

The Australian energy sector is transforming rapidly as the Australian economy transitions towards a decarbonised net-zero future. Federal and State Governments are committed to net zero targets, with the Victorian Government committing to net zero emissions by 2045. To facilitate the energy transition, recent changes have been made to the National Electricity Objective (**NEO**) in the National Electricity Law (**NEL**) to help achieve emission reduction targets set by participating jurisdictions.

While many aspects of this transformation remain uncertain, it is clear that the transformation is accelerating and the energy market in 2045 will look vastly different from today. As a regulated electricity distribution network in Victoria, JEN has a societal responsibility to facilitate this energy sector transformation, playing the key role of distributing electricity within the north and west of the Melbourne metropolitan area.

The accelerated pace of the energy transition presents both opportunities and uncertainties for JEN and our stakeholders. We are seeing an increase in the number of rooftop solar systems, more batteries, and increased electric vehicles. There's growing interest in communal energy solutions like shared solar installations, virtual power plants, and community batteries. CER are now more accessible than ever.

JEN's mission is to connect our customers to a renewable energy future. To deliver on this commitment, JEN's distribution network assets need to be capable of delivering an affordable, safe and reliable electricity supply that meets our customers' expectations, in a manner that is compliant with all regulatory obligations. This includes a focus on preparing the network for the future, leveraging new technologies and cost efficiencies to improve network competitiveness and customer outcomes.

This vision begins and ends with our customers, who are driving the transition to a future state. Their choices and preferences will heavily influence the energy market transformation, from their uptake of CER to the influence they have on policymakers.

To deliver on JEN's vision for the energy market transition, this CER Integration Strategy recommends a roadmap of least-regrets programs of work that facilitate the energy sector transformation over the next decade, having the flexibility to adapt and deliver customer net benefits to any of the credible future-state scenarios considered in this strategy (or combination thereof). These roadmap activities are complemented by a series of signposts – key events or market developments that indicate the future is heading more towards one of the three scenarios than another. Careful monitoring of these signposts will assist us in flexing our activities accordingly.

JEN's three future-state scenarios

To manage uncertainty risk with the energy transformation, in developing this CER Integration Strategy we have weighted three credible future-state scenarios in 2045 and detailed a set of high-level least regret activities as part of a roadmap to address the identified needs. The three scenarios we have considered (informed by Australian Energy Market Operator's (**AEMO's**) 2023 IASR[2]) are neutral (which we consider is most likely), low and high scenarios.

The three scenarios were founded on a set of fundamental megatrends and drew on internally consistent but different combinations of divergent outcomes in the areas of key uncertainties. The scenarios reflect the boundaries of possible future state scenarios, recognising that the more probable future state will be some

[1] SGSPAA Group, *Sustainability Report, Sustainability in Focus*, 2023; available: here

[2] AEMO, *Inputs, Assumptions and Scenarios Report (IASR)*, 2023.

combination of elements of all of these scenarios. The scenarios are distinguished by different assumed increases in electricity demand and consumption, distributed solar PV systems, plug-in electric vehicle (**EV**) usage, and electrification of gas, relative to today. Common opportunities from the three scenarios include:

- the need for visible and controllable CER to support power system security and the efficient operation of the distribution network (both high-voltage and low-voltage networks); and
- the need to adapt the distribution network to facilitate and enable CER operation at the least cost, supported by flexible import and export services, and improved voltage and power quality compliance.

JEN's CER Integration Strategy

The guiding ambitions for JEN's CER Integration Strategy focus on four key opportunities:

- **Optimise performance** – optimise the performance of current assets in response to customers' affordability concerns, by applying digital technology overlays over the existing assets. This includes leveraging Advanced Metering Infrastructure (**AMI**), condition monitoring, data analytics and other machine-learning and automation technologies.
- **Modernise the grid** – enable and support the uptake of CER on the network, including flexible services using Dynamic Operating Envelopes (**DOE**) to remove static export and import limits, reduce CER curtailment, improve CER exports, and improve voltage, supply quality and system security compliance.
- **Seed the market** – stimulate growth in the efficient use of CER to support the broader market, including data visibility for customers, enhanced tariffs such as for solar soak and EV charging, and use common communication protocols such as CSIP-Aus to support CER aggregation by market service providers.
- **Build organisational capability** – to undertake the activities above, we will build new capabilities across our systems, processes and people. This requires a focus on a culture that is customer-focused and encourages innovation, with much closer collaboration between the network and ICT functions of the business. It requires investment in advanced systems to manage more complex operations, communications and data, which will support building skills in big data and cybersecurity, as well as enhancing commercial acumen.

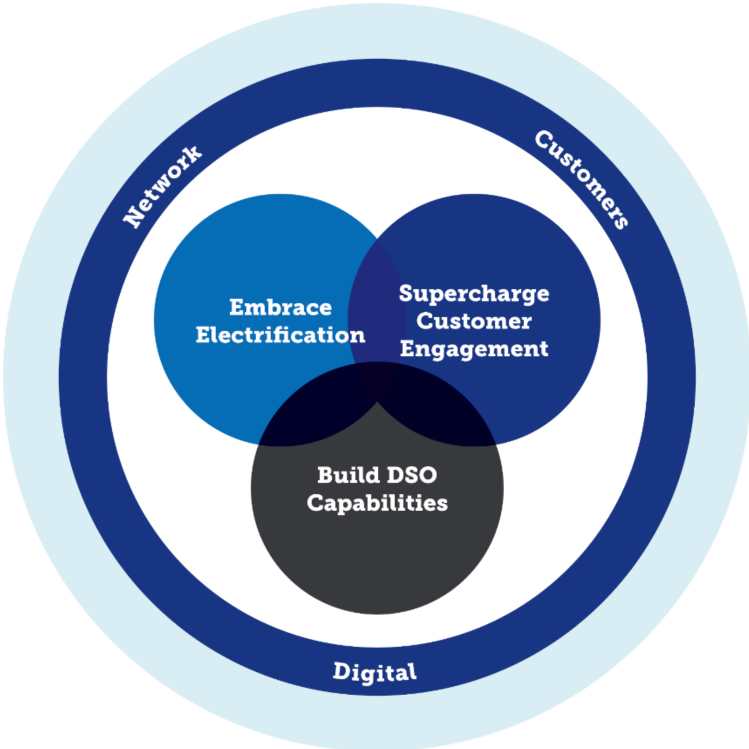
In order to deliver a network of the future for the evolving needs of customers and to empower Victorians to reach net zero by 2045, JEN's CER Integration Strategy is driven by opportunities to:

- **Embrace electrification** – Adapt the electricity distribution network to accommodate the additional demands expected from the electrification of the gas and transport sectors and for the evolving needs of our new and existing electricity customers.
- **Build future capabilities** – Continue to adopt digital systems and enhanced distribution services that support the energy transition to enable and facilitate competition and new services for energy market participants using enhanced applications, processes, automation, data and analytics, including functions that support AEMO in its role of maintaining power system security.

In pursuing initiatives to deliver on the above opportunities that meet our customers' service expectations they require in the transformed energy market, we will **supercharge customer engagement.** This will involve using a strategic multipronged approach to minimise the costs of adapting the network for the energy transition, maximising the capabilities of our existing network, and using pricing incentives, non-network alternatives and other flexible distribution services that enable and optimise CER. JEN also has a number of customer engagement initiatives planned over the next regulatory control period. These initiatives form part of our regulatory proposal, which includes energy literacy and building a new customer portal that provides tailored information to empower customers to make decisions on sustainable energy usage among other things.

To deliver the programs of work that support JEN's CER Integration Strategy, we will need to make changes to our network operations (Asset Management) and develop new Digital capabilities. Figure 1.1 illustrates the inter-relationships between the drivers for change, how they link to customers, the physical electricity distribution network, and digital technology to facilitate a smooth energy transformation at an efficient cost.

Figure 1.1 – Drivers of JEN's CER Integration Strategy



Programs of work delivering our CER Integration Strategy

In developing programs of work that support our CER Integration Strategy to facilitate the energy transformation we will seek to achieve the following outcomes for customers:

- maintain distribution network reliability, quality of supply, and resilience
- support power system security, stability and optimisation
- provide fair and cost-effective distribution network access and CER enablement
- provide and utilise network capacity in an efficient, economic, coordinated and timely manner
- enable and facilitate competition and new services for energy market participants; and
- meet our regulatory obligations.

We have identified three programs of work which we consider support our CER Integration Strategy and will achieve the above customer outcomes:

- **Grid Stability and Flexible Services Program** – the need for JEN to develop a Distributed Solar PV (**DPV**) Backstop Capability[3] and a Distributed Under-Frequency Load Shedding (**Distributed UFLS**) Scheme as two distinct grid stability applications to strategically respond to the challenges and opportunities associated with increasing numbers of CER, and their associated influences on power system security and network operating limits. The applications developed from this strategy are supported by a new and staged Distributed Energy Resource Management System (**LV-DERMS**) platform to achieve near real-time optimised control of CER

[3] DPV Backstop Capability is a committed project and are deployed in different stages in 2024 and 2025 to integrate with JEN's existing system for the required automation.

active power operating envelopes to keep the grid stable and to deliver flexible export and import distribution services using Dynamic Operating Envelopes (**DOEs**), facilitated by a CSIP-Aus utility server.

- **Voltage and Power Quality Management Program** – the need for a voltage and power quality management program to strategically respond to the challenges and opportunities associated with increasing CER penetration and the associated influences on network voltage and power quality. The applications developed from this strategy are supported by a new and staged Dynamic Voltage Management (**DVM**) system platform to achieve near real-time optimised control of network voltage and reactive power flow to maintain compliant voltages and reduce CER curtailment, using enhanced Volt-VAr control (**VVC**) integrated with JEN's Advanced Metering Infrastructure (**AMI**) assets.

- **Data, Visibility and Analytics Program** – the need for further digitalisation of network operations functions using network analytics applications. The program includes a network analytics applications program of work, and two application enablers: a Strategic Network Analytics Platform (SNAP) and near real-time AMI data. Network analytics application examples include: simulate new and moved connections, connection approvals, detection of wrong connections, near real-time power quality data for field crews, detect and predict network faults, and regulatory data collection obligations.

These programs of work set out least-regrets investment roadmaps, providing a prudent optimum balance between risk, expenditure and uncertainty, to meet the identified needs of the energy sector transformation. They are cost-effective non-network alternatives compared to building more network assets, to accommodate more CER and therefore address our customers' competing expectations: affordability vs maintaining reliability, automation, and support for renewables.

Key customer benefits include:

- **CER enablement** – improved export capability and reduced CER curtailment, justified using the Australian Energy Regulator's (**AER**) Customer Export Curtailment Value (**CECV**)[4] methodology

- **Reliability of supply** – maintained reliability of supply, by managing and adapting to the changes in electricity demand from CER uptake and usage of the network, the electrification of the gas and transport sectors, and the change in new and existing customers' requirements for electricity, justified using the AER's Values of Customer Reliability (**VCR**)[5] methodology; and

- **Regulatory compliance** – improved appliance safety and reduced consumption by maintaining voltages within regulatory limits and satisfying system security through enabling grid stability by AEMO and power quality regulatory requirements using a least-cost approach to achieving our compliance obligations.

We discuss these programs of work in more detail in section 4.

4 AER, *Customer Export Curtailment Value (CECV) methodology*, July 2024.

5 AER, *Values of Customer Reliability (VCR) methodology*, December 2023.

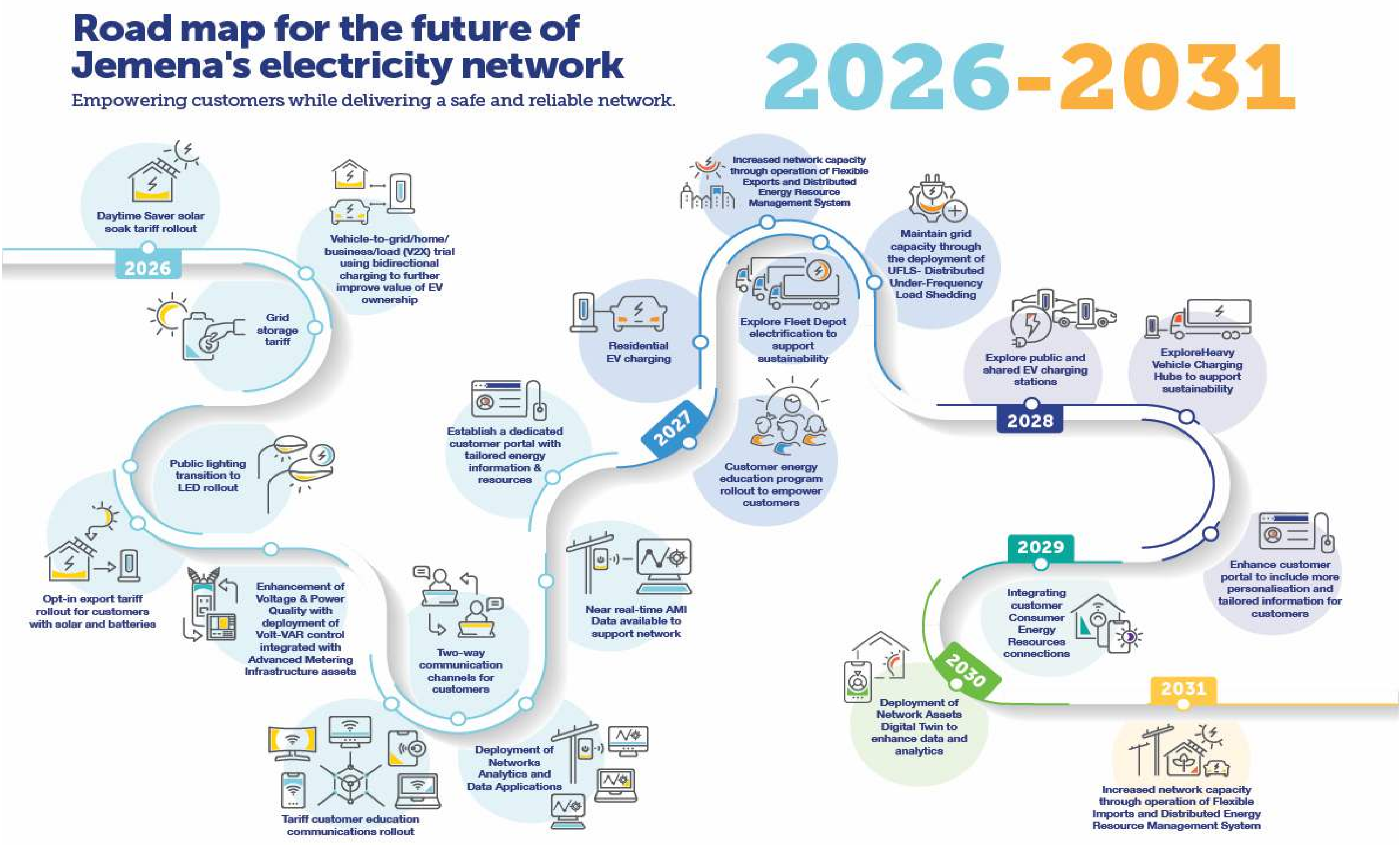


Figure 1–2: Jemena's Roadmap to the future

1. Background

1.1 Jemena's electricity network

JEN is the licensed electricity distributor for the northwest of Melbourne's greater metropolitan area. The service area ranges from Gisborne South, Clarkefield and Mickleham in the north, to Williamstown and Footscray in the south, and from Hillside, Sydenham and Brooklyn in the west, to Yallambie and Heidelberg in the east. Our electricity distribution network services over 387,000 customers in Melbourne's city fringe and its north-western suburbs, covering approximately 950 square kilometres.

1.2 JEN's vision in the future energy market

JEN's mission is to connect our customers to a renewable energy future. To deliver on this commitment, JEN's distribution network assets need to be capable of delivering an affordable, safe and reliable electricity supply that meets our customers' service expectations in a transformed energy market, in a manner that is compliant with all regulatory obligations. This includes a focus on preparing the network for the future, leveraging new technologies and cost efficiencies to improve network competitiveness and customer outcomes.

This vision begins and ends with our customers, who are driving the transition to a future state. Their choices and preferences will heavily influence the energy market transformation, from their uptake of CER to the influence they have on policymakers. JEN's vision in a future energy market is:

- **Customer-focused** – In line with our desire to be more customer-focused and community-minded, this vision sees us playing an important role in supporting individual customer choice.
- **Supportive of the energy transition** – We play a key enabling role in transitioning towards a resilient and clean energy future by facilitating higher renewable energy uptake, more efficient use of CER and unlocking greater value for customers and intermediaries to make these resources cheaper.
- **Supportive of reliable and efficient energy services** – Aside from customers and intermediaries, we also benefit by leveraging our CER portfolio to improve the security, reliability and overall resilience of the network through lower-cost options. JEN is faced with operating in a rapidly changing energy landscape. Disruptive impacts on distribution networks, particularly those triggered by the distributed renewable energy transition, are changing the way our customers use electricity networks.

While many of our core capabilities around asset management, planning, maintenance and operations remain, as we transition to the future energy market we need to utilise our people and our assets, supported by advanced digital systems, to enhance our customers' choices and preferences in a way that generates further benefits for our customers. We will need to adapt and strategically respond to the evolving energy market with a more proactive, technologically, data-driven approach to the management of our network. Our vision of connecting our customers to a renewable energy future relies on us working to seamlessly integrate all of the layers of an evolving system.

Our people, processes, technology and culture support a business that excels at owning, planning, designing, building, managing, operating and maintaining a modernised grid that accommodates the rapid connection of a range of new technologies.

The operation of the physical assets feeds a rich layer of customer and network data that can be mined to support a range of advanced distribution services. This includes data-enabled energy services for trusted partners who serve customers' needs with simple, cost-effective products and services. These products and services also have the potential to provide a service to the network, making it more reliable, secure, better utilised, better planned, better managed, and lower-cost to operate and maintain.

We support individual customer choice but also leverage this choice to support the efficiency of the system overall, for the benefit of all of our customers.

2. Energy market transition

While many aspects of the energy market transition remain uncertain, the transformation is accelerating, and the energy market in 2045 will look vastly different from today. Due to the transformation of the energy market, the role of the electricity distribution system is also changing. While traditionally a relatively simple link in the supply chain from large-scale fossil fuel generators to customer loads, the distribution business of the future will need to serve a far more complex environment.

Significant policy change is supporting the energy market transition and global 'megatrends' are being observed to give effect to the transition. The global megatrends shown in Figure 2.1 are influencing our customer needs and expectations, and informing the development of government policies, rules and regulations, all of which provide the drivers, objectives and frameworks for JEN to adapt its network and help facilitate the energy market transformation.

Figure 2.1 – Global Megatrends

In addition, increasingly competitive markets and offerings are giving consumers a broader range of choices, and markets are also increasingly emphasising customer centricity.

With the energy system transformation and the associated impact of CER uptake and electrification, distributors will face significant challenges in maintaining network reliability, power system security, and quality of supply to continue meeting regulatory requirements and changing customer needs.

These trends are discussed below.

2.1 Policy supporting the energy transition

Australian emission reduction policies are legislated in the Climate Change Act (2022), with emission reduction targets of 43% below 2005 levels by 2030 and net zero by 2050. Australia's Climate Change Act acts as 'umbrella' legislation for greenhouse gas reduction targets. Key policies and programs include the:

- Powering Australia Plan[6] to support the decarbonisation of electricity generation and the uptake of EVs, with a commitment by the Commonwealth Government for renewable generation to achieve an 82 per cent share of renewable generation by 2030; and
- Safeguard Mechanism[7] (in place since 2016 with reforms in 2023) to drive business and industrial emissions reduction for facilities emitting more than 100,000 tonnes of carbon dioxide equivalent (CO2-e) per year.

The Victorian Government's emission reduction policies are legislated in Victoria's Climate Change Act (2017). In October 2022, new, more ambitious emission reduction targets were set with targets of 28-33% below 2005 levels by 2025, 45-50% by 2030, 75-80% by 2035 and net zero by 2045[8]. The government legislated these more ambitious targets in March 2024.

In addition to the emission reduction targets, Victoria has a suite of energy-related programs and roadmaps supporting the achievement of those targets, including Solar Homes[9] to support the uptake of rooftop solar PV and other programs delivered through Solar Victoria, the Zero Emissions Vehicles Roadmap[10], and the Gas Substitution Roadmap[11].

In 2023, the NEO in the NEL was updated to include consideration of reducing greenhouse gas emissions set by participating jurisdictions. The 2026-31 regulatory control period (next regulatory period) will be the first under the export pricing rule change made by the AER in May 2022, which aims to facilitate small-scale solar into the grid and support the growth of batteries and EVs. It allows for network energy businesses to propose two-way pricing, i.e. pricing on both consumption and export of electricity, as part of their AER-approved tariff structure statements.

2.2 Global megatrends

The global megatrends being observed in the transforming energy market include:

- **Decarbonisation** – a transition from fossil fuels to renewables across all sectors of the economy (including electrification), driven by the need to reduce carbon dioxide emissions for climate change mitigation towards net zero;
- **Decentralisation** – a transition from large, centralised generation sources to smaller distributed generation sources, much of which is being installed in the distribution networks within customer premises; and
- **Digitalisation** – exponential growth in the global demand for digital data and the information systems required to support, process and utilise that data, affecting all sectors of the global economy including the energy market.

2.3 Changing customer needs

Increasingly competitive markets and offerings are giving consumers a broader range of choices. Markets are also increasingly emphasising customer centricity. The megatrends described above are resulting in technological developments that change how customers can interact with the electricity system, either through energy retailers, independent aggregators or directly with networks. In recent years, there has been an increase in customers who

6 Powering Australia Plan, Commonwealth of Australia, 2023.

7 Safeguard Mechanism – DCCEEW, 2023.

8 Climate action targets, Victorian Government, 2023.

9 Solar Homes Program, Solar Victoria, 2023.

10 Zero Emissions Vehicles Roadmap, DEECA, 2021.

11 Gas Substitution Roadmap, DEECA, 2023.

are shifting from a passive relationship with the electricity system into one where they more actively manage their use of energy.

Besides technological developments such as home energy management systems, solar panels and battery storage, which allow customers to engage with their energy retailers and networks, other factors have contributed to this shift in consumer attitude. These include rapidly falling CER installation costs at the residential level, significantly improving the payback period of customer investments, and rising electricity prices that further improve the attractiveness of these investments.

New products and services are emerging that allow customers to generate and store their electricity, and more importantly, allow them to manage their energy use. For example, residential customers with a home energy management system and storage can become actively involved in modifying their energy expenditure by monitoring their actual consumption in real-time. Market innovations can also provide energy consumers with greater variety and choice in how they purchase energy services. These changing dynamics between consumers and the electricity system will continue to evolve with the availability and continued uptake of enabling technologies such as solar PV, battery storage and smart grids.

Besides active CER customers who manage their energy bills, some passive customers do not or cannot seek to invest in CER. As a result, either by choice or circumstance, some customers will continue to use the network traditionally and will not be involved in this customer shift. In practice, customer groups are much more complex than these two categories, and as such JEN considers a range of customer segmentations based on distinct patterns of customer engagement and behavioural traits.

As the energy market transitions, a significant proportion of generation will originate from customers and flow back into the network, and many customer devices will seek to connect to and interact with the electricity system. This transition will be heavily influenced by customers, governments and regulators, as well as other changes in the external market environment.

CER connected to our network is continuing to increase and is becoming a crucial resource to support, manage and utilise the distribution network. JEN has already seen strong growth in network-connected, passive distributed solar photovoltaic (**DPV**) system installations by our customers and this is likely to continue. Other emerging, potentially more active CER technology (including customer and community storage and EVs), present further challenges and opportunities for network integration.

These trends will cause an increasing proportion of the overall power system generation to be located within the distribution network. Therefore, power system security will become increasingly more important and complex for JEN to manage on behalf of AEMO as CER penetration continues to rise. Furthermore, LV network planning and operation will become increasingly more important and complex because most CERs are being connected within customer premises within our LV networks. With the networks traditionally designed for one-way passive loads, this change has direct and profound implications on our customers' experience with the network, and therefore on the way JEN manages this part of the network.

Appendix A: Factors affecting the transforming energy market, provides more detail on the policy changes and megatrends and the technical and operational challenges faced by distribution network businesses.

3. Future state scenarios

Given that the Australian energy market is transforming at a rapid rate, a least-regrets scenario-based investment approach is needed to manage the uncertainty risk around the transformation.

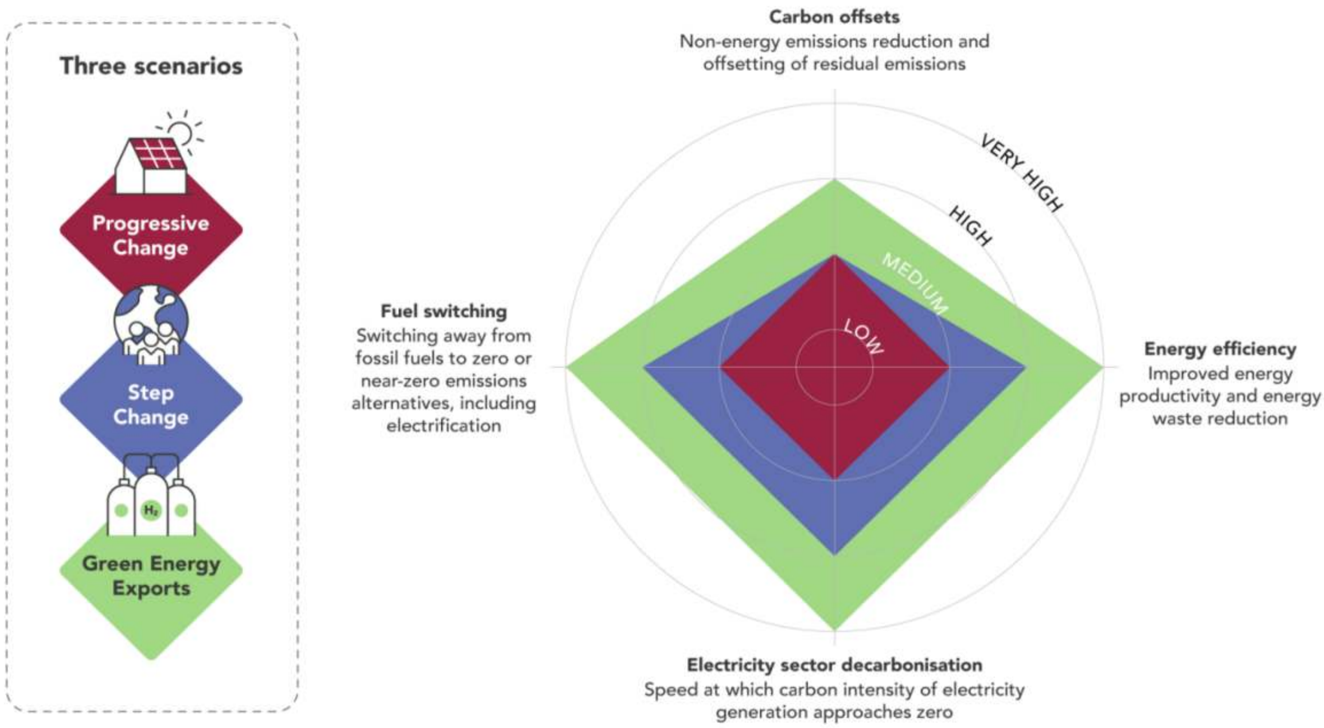
JEN has identified three potential future-state scenarios in 2040 that the CER Integration Strategy roadmap must develop high-level least regret activities for. The three scenarios (informed by the scenarios in AEMO's 2023 IASR) were founded on the observed global megatrends and draw on internally consistent, but different, combinations of divergent outcomes in the areas of key uncertainties. These scenarios reflect the boundaries of possible future state scenarios, recognising that the more probable future state will be some combination of elements of all of these scenarios.

The scenarios are distinguished by different assumed increases in electricity demand and consumption, distributed solar PV systems, plug-in EV usage, and electrification of gas, relative to today. JEN considers that the most likely scenario is defined as the **neutral scenario** and is centred mainly on the AEMO step change scenario.

3.1 AEMO's inputs, assumptions and scenarios

As part of its development process for the 2024 Integrated System Plan, AEMO developed its 2023 IASR[12] based on an extensive industry consultation process. The 2023 IASR scenarios have been refined to capture the latest information on the economic and technological changes expected over the coming decades, investment in CER and electrification of other sectors to decarbonise the Australian economy to achieve net zero. In its 2023 IASR, AEMO has defined three 2040 future-state scenarios, which are progressive change, step change and green energy exports with characteristics as illustrated in Figure 3.1

Figure 3.1 – AEMO's 2023 IASR Future-State Scenarios



Source: AEMO 2023 IASR (Figure 6)

12 AEMO, *Inputs, Assumptions and Scenarios Report*, July 2023.

As part of updating its 2024-forecasting-assumptions-update, AEMO has updated some key underlying assumptions for its future state scenarios, which are discussed below.

The update to AEMO's assumptions means for JEN that the rates of electrification, particularly EVs, VPPs and embedded storage, and particularly the step change and green energy export scenarios, are slower than what was forecast in 2023. Furthermore, the rates of solar PV growth, particularly the step change and progressive change scenarios, are faster than what was forecast in 2023.

3.1.1 Progressive change scenario

The Progressive Change scenario assumes Australia meets its current Paris Agreement commitment of 43% emissions reduction by 2030 and net zero emissions by 2050. In this scenario, energy transformation investments continue, but economic, supply chain and geopolitical factors result in overall lower levels of growth. The purpose of this scenario is to test the needs of the power system with a slower energy transition.

The progressive change scenario is a lower growth, slower change scenario than the other two scenarios. By 2040, under this scenario in the NEM:

- EVs are forecast to comprise 32% of road transport, of which 56% are on convenience charging
- business electrification achieves 49% of its potential and residential 50% of its potential; and
- distributed PV generation increases by 188% and household battery penetration is 3%.

3.1.2 Step change scenario

The Step Change scenario achieves a higher level of energy transformation that supports Australia's contribution to limiting global temperature rise to below 2°C compared with pre-industrial levels. This scenario relies on a very strong contribution from consumers in the transformation, with continued investments in orchestrated CER. There is also strong transport and gas electrification. The purpose of this scenario is to test the needs of the power system to support strong decarbonisation of the electricity sector, supporting other sectors of the economy to decarbonise through electrification.

The step change scenario is a moderate growth, fast change scenario. By 2040, under this scenario in the NEM:

- EVs are forecast to comprise 60% of road transport, of which 46% are on convenience charging
- business electrification achieves 61% of its potential and residential 75% of its potential; and
- distributed PV generation increases by 321% and household battery penetration is 21%.

3.1.3 Green energy exports scenario

The Green Energy Exports scenario (previously referred to as the Hydrogen Superpower scenario) reflects very strong decarbonisation activities domestically and globally to limit temperature increases to 1.5°C. It builds further on the step change scenario to result in a rapid transformation of Australia's energy sectors, including stronger electrification and green fuel use. The purpose of this scenario is to test the implications and needs of the power system experiencing very rapid change from decarbonisation and supporting an expansion of the green energy economy.

The green energy exports scenario is a high-growth, fastest-change scenario. By 2040, under this scenario in the NEM:

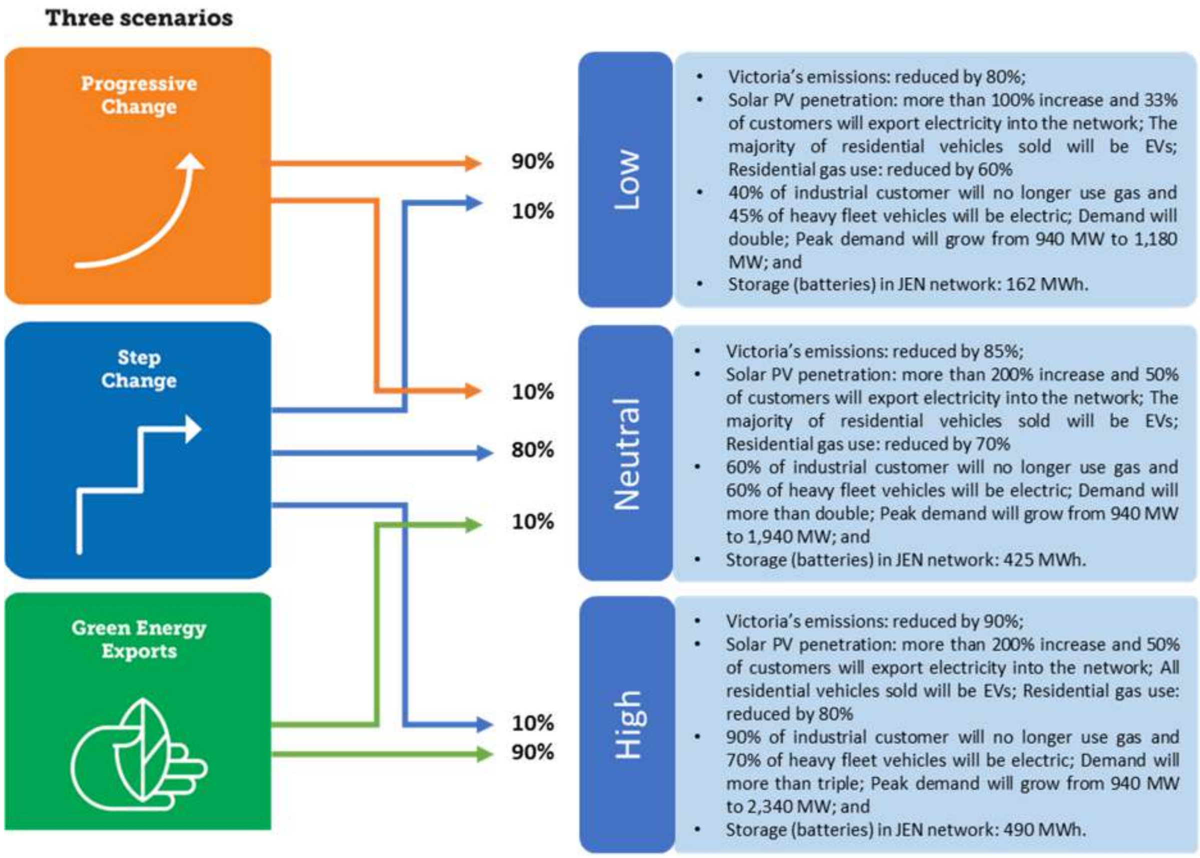
- EVs are forecast to comprise 72% of road transport, of which 38% are on convenience charging

- business electrification achieves 88% of its potential and residential 75% of its potential; and
- distributed PV generation increases by 383% and household battery penetration is 22%.

3.2 JEN's scenarios

In 2023, we engaged Blunomy to assess the AEMO scenarios in the context of JEN's operating environment and prepare low, neutral and high scenarios of our forecasts of CER uptake (by type), electrification, energy consumption, maximum and minimum demand, and customer numbers, based on weightings of the AEMO scenarios as illustrated in Figure 3.2. We updated those forecasts in 2024.

Figure 3.2 – JEN's Future-State Scenarios – Weighting of AEMO Scenarios



Key aspects of the scenarios relevant to JEN's service area include:

- Society remains committed to decarbonising and Victoria is on track to achieve net-zero by 2045. Supportive government policies and funding, coupled with the decreasing cost of renewables and continuing environmental, social, and corporate governance imperatives, are delivering a transition of the energy mix away from coal and gas.
- Regulation and digitalisation of the network have supported the market shift to a two-sided regime to facilitate the penetration of consumer energy resources. The physical network is more actively managed to maintain resilience, while the 'digital network' of customers and energy management is made available for market providers.

- End-customers primarily migrate to direct electrification with the currently available technology set (PV, batteries, gas electrification, EVs, etc.) remaining the most cost-competitive and being enabled by digital technologies reaching maturity.
- Customers expect their energy to be reliable, renewable and affordable with digital, flexible, and multi-faceted service offerings available that cater to customers' energy management needs and desire for simplicity and ease.

The common opportunities from the three scenarios include:

- the need for visible and controllable CER to support power system security and the efficient operation of the distribution network (both high-voltage and low-voltage networks); and
- the need to adapt the distribution network to facilitate and enable CER operation at the least cost, supported by flexible import and export services and improved voltage compliance.

Regardless of the future state of the network and the potential changes to the way the NEM operates, JEN has identified several least-regret activities as part of the CER Integration Strategy that will address the aspects common to all future scenarios to unlock benefits for its customers. Implementing these activities will ultimately benefit all of JEN's customers by allowing them to maximise the opportunities available from increasing CER and optimise the utilisation of existing network assets, reducing the costs of delivering network services and keeping downward pressure on wholesale market prices.

The programs of work identified from these strategies set out least-regrets investment roadmaps, providing a prudent optimum balance between risk, expenditure and uncertainty, to meet the identified needs of the network for the energy transformation. The key benefits include:

- **CER enablement** – improved export capability and reduced CER curtailment, justified using the AER's Customer Export Curtailment Value (**CECV**)[13] methodology
- **Reliability of supply** – maintained reliability of supply, by managing and adapting to the changes in electricity demand from CER uptake and usage of the network, the electrification of the gas and transport sectors, and the change in new and existing customers' requirements for electricity, justified using the AER's Values of Customer Reliability (**VCR**)[14] methodology; and
- **Regulatory compliance** – improved appliance safety and reduced consumption by maintaining voltages within regulatory limits and satisfying system security through enabling grid stability by AEMO and power quality regulatory requirements using a least-cost approach to achieving our compliance obligations.

Our neutral, high and low scenarios are discussed below.

3.2.1 Neutral

The most likely scenario is defined as the **neutral scenario** and is centred mainly on the AEMO step change scenario (80% weighting, and 10% of the other two AEMO scenarios). By 2040, under this neutral scenario:

- Victoria is on a path to decarbonise its economy with an 85% emissions reduction
- solar PV installed capacity in JEN's area will more than triple, with approximately 1,280 MW of generation within our network
- the majority of residential vehicles sold will be EVs, accounting for approximately 60% of the car population (and rapidly growing)
- over half of our customers will use the network for two-way flows, optimising in real-time through digitally enabled data flows

[13] AER, *Customer Export Curtailment Value (CECV) methodology*, July 2024.

[14] AER, *Values of Customer Reliability (VCR) methodology*, December 2023.

- residential gas use will have been reduced by 70%, with households transitioning to electric appliances
- 60% of industrial customers will no longer use gas and 60% of heavy fleet vehicles will be electric
- consumption on the network will more than double from 4.2 TWh today to 10.4 TWh[15], and peak demand will also more than double from 940 MW to over 1,940 MW; and
- overall storage in the JEN network will be 425 MWh across home batteries.

3.2.2 High

The optimistic decarbonisation scenario is defined as **the high scenario** and is centred mainly on the AEMO green energy exports scenario (90% weighting) with a small component (10% weighting) from the step change scenario. By 2040, under this high scenario:

- Victoria is on a path to decarbonise its economy with a 90% emissions reduction
- solar PV installed capacity in JEN's area will more than triple, with approximately 1,300 MW of generation within our network
- all residential vehicles sold will be EVs, accounting for approximately 70% of the car population
- over two-thirds of customers will use the network for two-way flows, optimising in real-time through digitally enabled data flows
- residential gas use will have reduced by 80%, with households transitioning to electric appliances
- 90% of industrial customers will no longer use gas and 70% of heavy fleet vehicles will be electric
- consumption on the network will more than triple from 4.2 TWh today to 13.7 TWh[15], and peak demand will also more than double from 940 MW to over 2,340 MW; and
- overall storage in the JEN network will be 490 MWh across home batteries.

3.2.3 Low

The pessimistic decarbonisation scenario is defined as the **low scenario** and is centred mainly on the AEMO progressive change scenario (90% weighting) with a small component (10% weighting) from the step change scenario. By 2040, under this low scenario:

- Victoria is on a path to decarbonise its economy with an 80% emissions reduction
- solar PV installed capacity in JEN's area will more than double, with approximately 900 MW of generation within our network
- the majority of residential vehicles sold will be EVs, accounting for approximately 30% of the car population (and rapidly growing)
- over one-third of customers will use the network for two-way flows, optimising in real-time through digitally enabled data flows;
- residential gas use will have been reduced by 60%, with households transitioning to electric appliances
- 40% of industrial customers will no longer use gas and 45% of heavy fleet vehicles will be electric
- consumption on the network will double from 4.2 TWh today to 8.5 TWh[15], and peak demand will also grow from 940 MW to over 1,180 MW; and
- overall storage in the JEN network will be 162 MWh across home batteries.

[15] Energy consumption data extracted from Blunomy's energy forecast, 2024.

4. CER integration strategy and roadmap

This CER Integration Strategy is the overarching strategy for JEN's asset management and ICT strategies, setting the basis for the strategic direction from which JEN's strategies and programs are informed. The guiding ambitions for JEN's CER Integration Strategy focus on four key opportunities:

- **Optimise performance** – optimise the performance of current assets in response to customers' affordability concerns, by applying digital technology overlays over the existing assets. This includes leveraging AMI, condition monitoring, data analytics and other machine-learning and automation technologies.
- **Modernise the grid** – enable and support the uptake of CER on the network, including flexible services using DOE to remove static export and import limits, reduce CER curtailment, improve CER exports, and improve voltage, supply quality and system security compliance.
- **Seed the market** – stimulate growth in the efficient use of CER to support the broader market, including data visibility for customers, enhanced tariffs such as for solar soak and EV charging, and use common communication protocols such as CSIP-Aus to support CER aggregation by market service providers.
- **Build organisational capability** – to undertake the activities above, we will build new capabilities across our systems, processes and people. This requires a focus on a culture that is customer-focused and encourages innovation, with much closer collaboration between the network and ICT functions of the business. It requires investment in advanced systems to manage more complex operations, communications and data, which will support building skills in big data and cybersecurity, as well as enhancing commercial acumen.

4.1 JEN's CER integration strategy

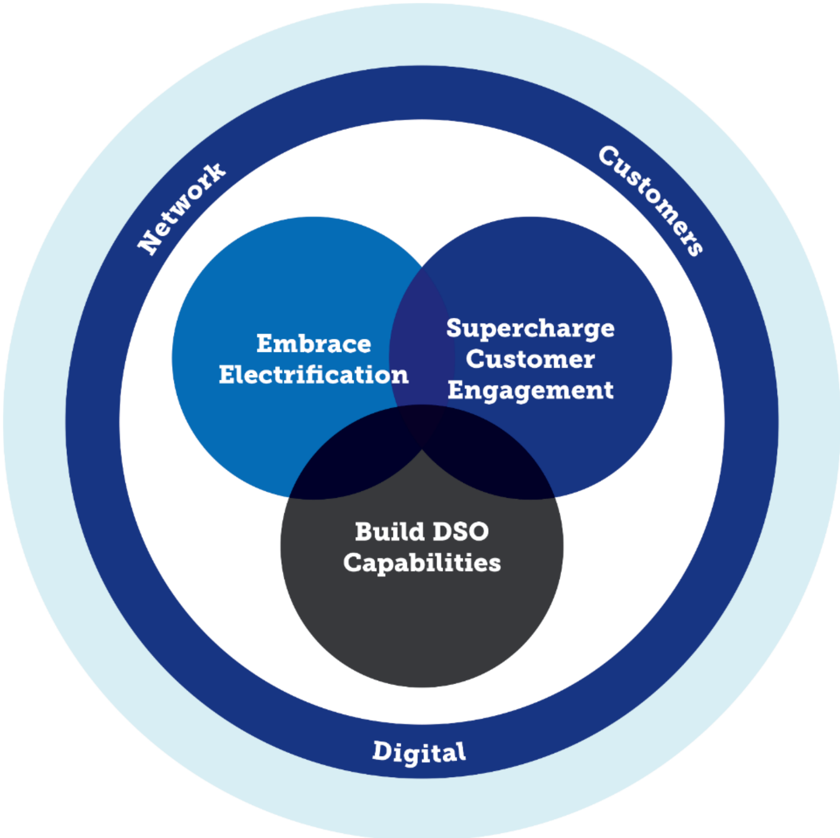
In order to deliver a network of the future for the evolving needs of customers and to empower Victorians to reach net zero by 2045, JEN's CER Integration Strategy is driven by opportunities to:

- **Embrace electrification** – Adapt the electricity distribution network to accommodate the additional demands expected from the electrification of the gas and transport sectors and for the evolving needs of our new and existing electricity customers.
- **Build future capabilities** – Continue to adopt digital systems and enhanced distribution services that support the energy transition to enable and facilitate competition and new services for energy market participants using enhanced applications, processes, automation, data and analytics, including functions that support AEMO in its role to maintain power system security.

In pursuing opportunities to deliver on the above opportunities that meet our customers' service expectations they require in the transformed energy market, we will **supercharge customer engagement.** This will involve using a strategic multipronged approach to minimise the costs of adapting the network for the energy transition, maximising the capabilities of our existing network, using pricing incentives, non-network alternatives and other flexible distribution services that enable and optimise CER. Jemena also has a number of customer engagement initiatives planned for the next regulatory control period. These initiatives form part of our regulatory proposal, which includes energy literacy and building new customer portal that provide tailored information to empower customers to make decisions on sustainable energy usage among other things.

Figure 4.1 illustrates the inter-relationships between the drivers for change, how they link to customers, the physical electricity distribution network, and digital technology to facilitate a smooth energy transformation at an efficient cost.

Figure 4.1 – JEN's CER Integration Strategy opportunities



Adopting programs of work during the energy transformation that support these key opportunities will allow us to achieve the following outcomes for customers:

- maintain distribution network reliability, quality of supply, and resilience
- support power system security, stability and optimisation
- provide fair and cost-effective distribution network access and CER enablement
- provide and utilise network capacity in an efficient, economic, coordinated and timely manner
- enable and facilitate competition and new services for energy market participants; and
- meet our regulatory obligations.

We have identified three programs of work which we consider support our CER Integration Strategy and will achieve the above customer outcomes:

- **Grid Stability and Flexible Services Program** – a program that articulates the need for JEN to develop a DPV Backstop Capability[16] and a Distributed UFLS Scheme as two distinct grid stability applications to strategically respond to the challenges and opportunities associated with increasing numbers of CER, and their associated influences on power system security and network operating limits. The applications developed from this strategy are supported by a new and staged LV-DERMS platform to achieve near real-time optimised control of CER active power operating envelopes to keep the grid stable and to deliver flexible export and import distribution services using DOEs, facilitated by a CSIP-Aus utility server.

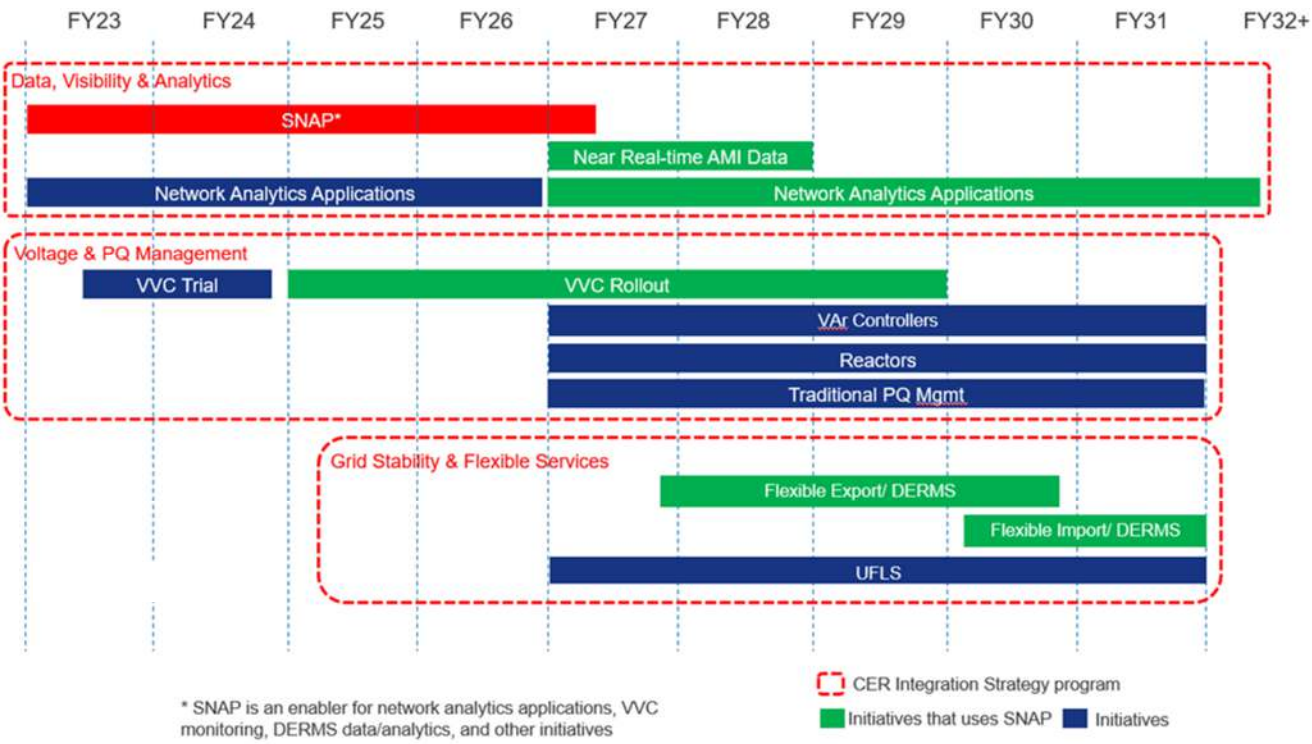
16 DPV Backstop Capability is a committed project and are deployed in different stages in 2024 and 2025 to integrate with JEN's existing system for the required automation.

- **Voltage and Power Quality Management Program** – a program to strategically respond to the challenges and opportunities associated with increasing CER penetration and the associated influences on network voltage and power quality. The applications developed from this strategy are supported by a new and staged DVM system platform to achieve near real-time optimised control of network voltage and reactive power flow to maintain compliant voltages and reduce CER curtailment, using enhanced VVC integrated with JEN's AMI assets.

- **Data, Visibility and Analytics Program** – a program that articulates the need for further digitalisation of network operations functions. The program includes a network analytics applications program of work, and two network analytics application enablers: a Strategic Network Analytics Platform (SNAP) and near real-time AMI data. Network analytics application examples include: simulate new and moved connections, connection approvals, detection of wrong connections, near real-time power quality data for field crews, detect and predict network faults, and regulatory data collection obligations.

The timelines for these programs of work with associated initiatives that involve building and strengthening capabilities is shown in Figure 4.2.

Figure 4.2 – JEN's CER Integration Strategy programs and initiatives



These programs of work set out least-regrets investment roadmaps, providing a prudent optimum balance between risk, expenditure and uncertainty, to meet the identified needs of the energy sector transformation. They are cost-effective non-network alternatives compared to building more network assets, to accommodate more CER and therefore address our customers' competing expectations: affordability vs maintaining reliability, automation, and support for renewables.

In addition, where appropriate JEN will consider the use of enhanced tariff and pricing mechanisms as complementary ways of adapting to the energy transformation, including the introduction of solar soak tariffs, electric vehicle charging tariffs and demand response incentive payments. These mechanisms are aimed at influencing customer behaviour to optimise the use of the existing distribution network and minimise capital investment to augment the network.

A summary of the purpose and roadmaps for each of the CER Integration Strategy programs and initiatives is detailed below. Further information is provided in the individual investment briefs.

4.2 Delivery of the programs

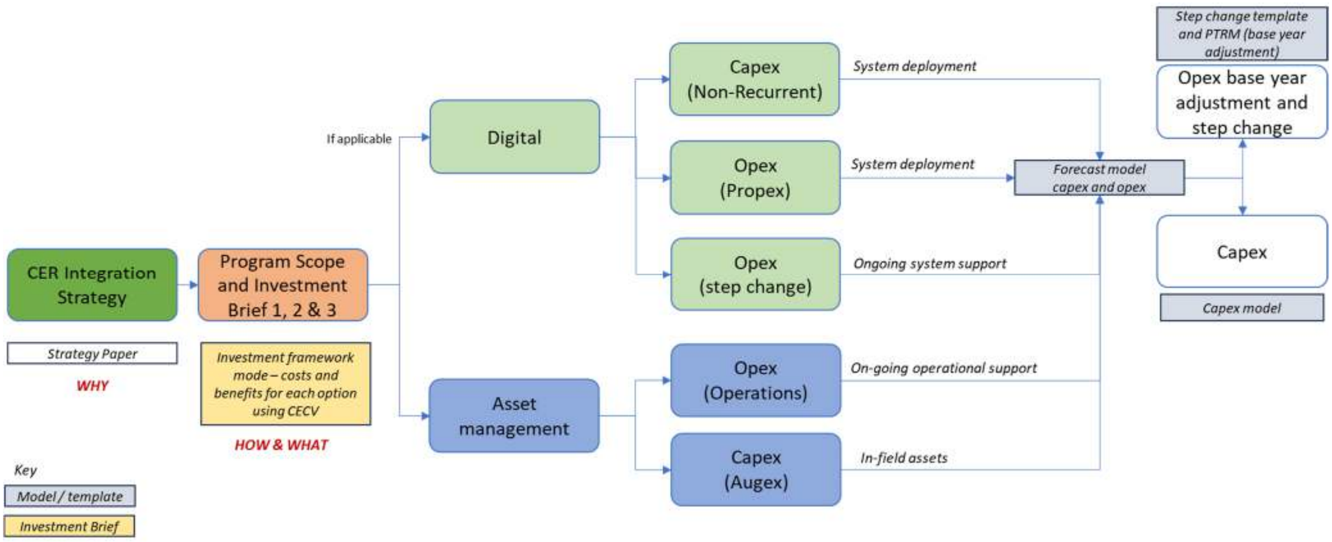
To deliver the programs of work that support JEN's CER Integration Strategy, we will need to make changes to our network operations (Asset Management) and develop new Digital (ICT) capability.

Collaboration between the ICT and Asset Management teams is increasingly vital for JEN with the growing digitalisation and complexity of the energy landscape. As the grid modernises with smart technologies and automation, ICT provides the digital infrastructure needed for real-time data collection and analysis, while Asset Management manage the physical infrastructure. Together, they ensure a resilient and adaptable grid capable of accommodating the demands of renewable energy integration, which relies on advanced digital tools such as machine learning to monitor grid health and manage load fluctuations.

Furthermore, the rise of digital systems brings heightened cyber threats, making it essential for the ICT and Asset Management teams to work closely to implement robust cybersecurity measures that protect both physical and digital assets. In addition, customer expectations for real-time energy usage data and personalised services require this collaboration to deliver efficient, customer-centric solutions. Finally, regulatory reforms in the electricity market demand new digital systems for compliance and market participation, further reinforcing the need for strong coordination between ICT and Asset Management functions.

Therefore, expenditure is required on ICT activities (non-recurrent capital expenditure (capex) for system development, project operating expenditure (propex) for system deployment and operating expenditure (trailing opex) for ongoing system support) and Asset Management (capex on in-field assets and opex for ongoing support) as shown in Figure 4.3. A detailed list of these projects is included in Appendix B: programs of work that support JEN's CER Integration Strategy.

Figure 4.3 – Delivery by Asset Management and Digital of JEN's CER Integration Strategy



We consider that we have the resourcing capability to deliver the programs proposed in this strategy. The availability of key resources (SMEs and field resources) is a low risk, with our mitigation being to have appropriate resourcing contingency and skills development plan in place, and to ensure that the project schedule is aligned with realistic resources availability. Delays due to the complexities of implementing new equipment can be derisked with lab-based proof-of-concept testing early in the project life-cycle to allow time to fix issues and minimise their impact on the overall project delivery timing. We have also undertaken proof of concept trials within the current period to minimise delivery risks.

4.3 Grid stability and flexible services program and roadmap

The Grid Stability and Flexible Services Program articulates the need for JEN to develop a DPV Backstop Capability and a Distributed UFLS Scheme as two distinct Grid Stability applications to strategically respond to the challenges and opportunities associated with increasing CER and the associated influences on power system security and network operating limits.

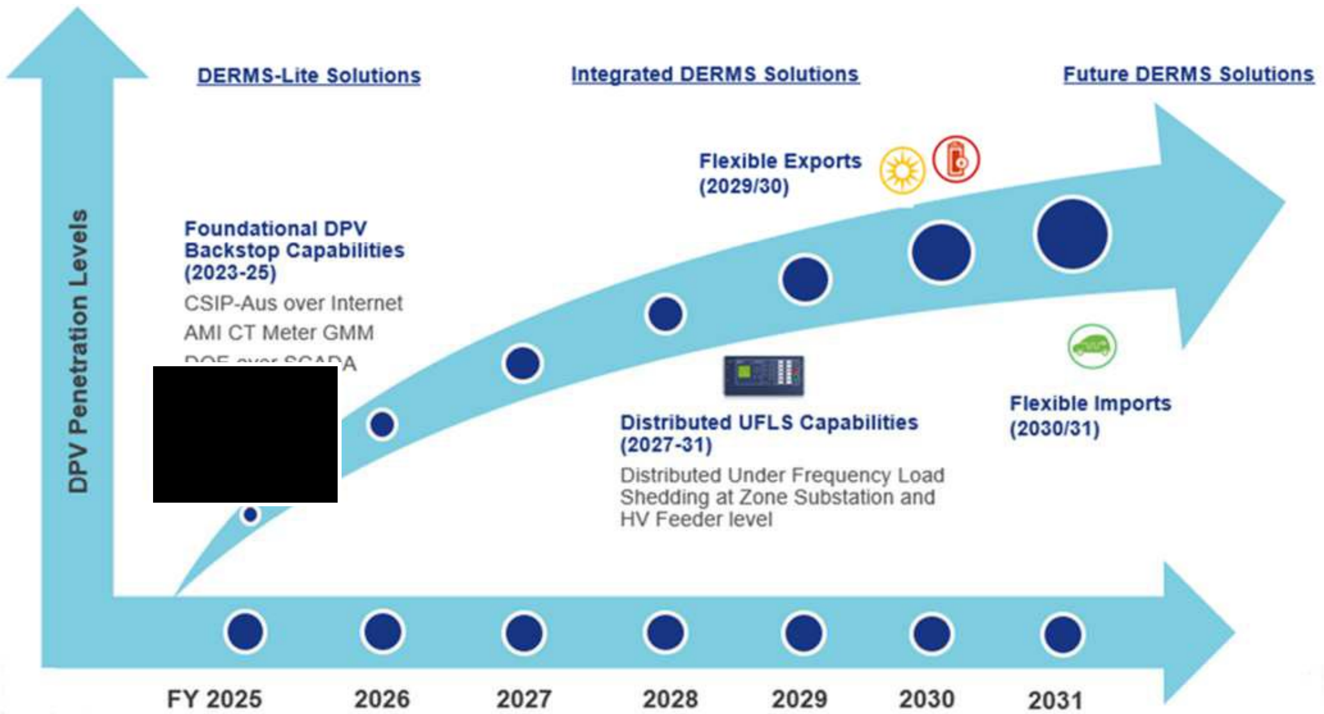
The AEMO forecasts[17] net minimum demand in Victoria to fall below its minimum acceptable operating threshold by late 2024. This poses the following challenges for maintaining power system security:

- **Supply-Demand Balance** – an oversupply of DPV generation that cannot be curtailed or interrupted, leading to a collapse of the power system following the unexpected disconnection of an interconnector; and
- **Under Frequency Load Shedding (UFLS)** – a scheme that disconnects load to mitigate power system collapse from a sudden drop in system frequency (triggered by a loss-of-generation event), becoming ineffective due to the presence of reverse power flows from DPV.

To support AEMO in addressing both of these emerging power system security needs, JEN requires grid stability applications to fulfil its power system security regulatory obligations. Furthermore, flexible services applications will enable JEN to strategically respond to the challenges and opportunities associated with increasing CER penetration and relevant impacts on our own network and support legislated emission reduction targets.

The applications developed from this program are supported by a new and staged LV-DERMS platform to achieve near real-time optimised control of CER active power operating envelopes to keep the grid stable and deliver flexible export and import services using DOEs, facilitated by a CSIP-Aus utility server. The proposed strategic roadmap for developing JEN's Grid Stability and Flexible Services capability to meet the identified needs for the next ten years is illustrated in Figure 4.4.

Figure 4.4 – JEN's Grid Stability & Flexible Services Program Roadmap



17 As at November 2024.

All programs are economically viable based on their estimated costs and market benefits, with the key driver for grid stability being to meet our regulatory compliance obligations under the National Electricity Rules (**NER**) for power system security (Clause 4.3.4(a), Clause 4.3.1(k)(2), and Schedule S5.1.10.1).

The activities required to implement the capabilities include:

- Foundational DPV Backstop capability (2023-2025)
    - Establish DOE Over SCADA for DPV > 200kVA as primary solution.
    - Establish CSIP-AUS for DPV 0-200kVA including:
        - Utility Server deployment, 1 October 2024, and
        - LV DERMS deployment, by 31 March 2025.
    - Establish GMM for DPV >30-200kVA, as an alternative solution to CSIP-AUS where the internet connectivity is not available, 1 October 2024.
- Flexible Exports (2028-2029)
    - Implementation duration from January 2028 to December 2029.
    - Expand DOE of SCADA and GMM using LV DERMS platform.
- Flexible Imports (2030-2031)
    - Implementation from January 2030 to March 2031.
- Foundational Distributed UFLS Capabilities (2027-2031)
    - Implementation of 7 terminal stations, from 2027 to 2031.

4.4 Voltage and power quality management strategy and roadmap

The Voltage and Power Quality Management Strategy articulates the need for a Volt-VAr Control program to strategically respond to the challenges and opportunities associated with increasing CER and the associated influences on network voltage, demand and power factor.

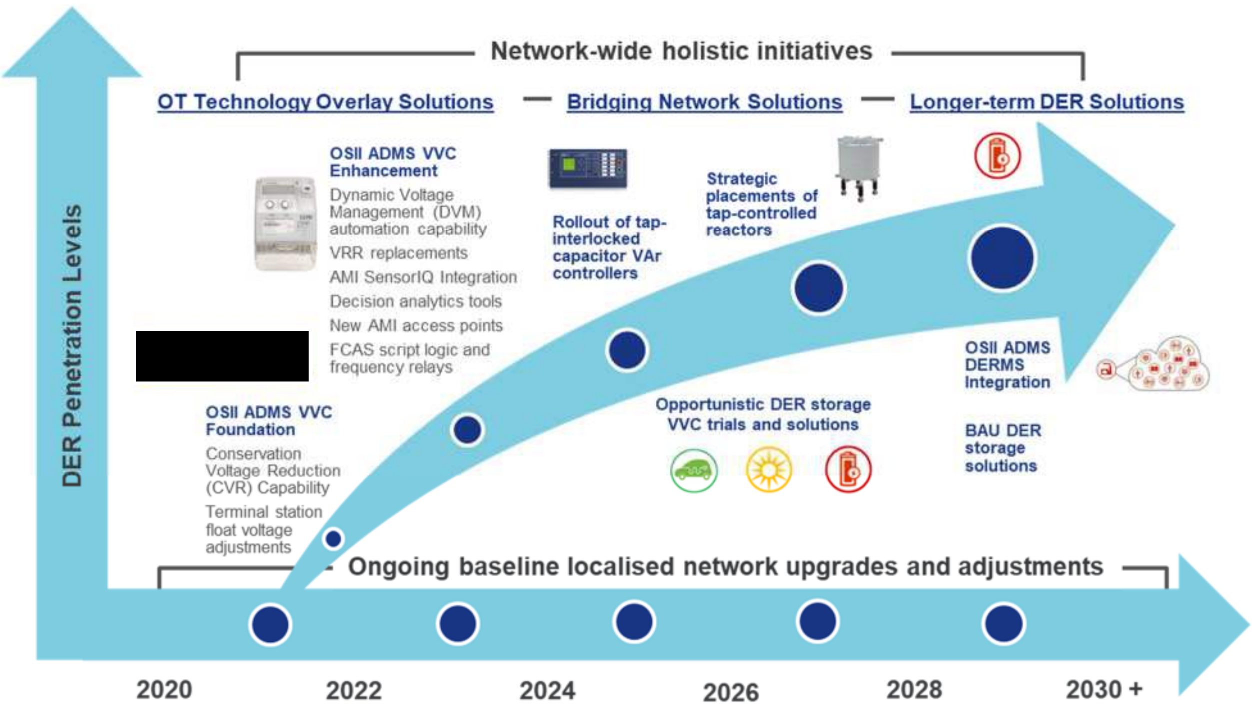
The Voltage and PQ Management program aims to:

- ensure voltage and power quality compliance for our customers across the distribution network;
- reduce both the safety risk and the elevated energy consumption of customer appliances that are exposed to high network operating voltages;
- reduce the amount of voltage-induced DER curtailment of customer inverters that are exposed to high network operating voltages;
- enable greater levels of customer DER exporting, by alleviating over-voltage limitations within the network;
- enable greater levels of customer imports and reduce the risk of customer appliances from damage, by alleviating under-voltage limitations within the network.

The applications developed from this strategy are supported by a new and staged DVM system platform to achieve near real-time optimised control of network voltage and reactive power flow to deliver compliant voltages and reduce CER curtailment using VVC and JEN's AMI assets.

The proposed strategic roadmap for the development of JEN's Voltage and Power Quality Management program to meet the identified needs for the next ten years is illustrated in Figure 4.5.

Figure 4.5 – Voltage and Power Quality Management Strategy Roadmap



All programs are economically viable based on their estimated costs and market benefits, with the key driver for voltage and power quality management being to meet our regulatory compliance obligations under the Victorian Electricity Distribution Code of Practice (**EDCoP**) for steady-state voltage and quality of supply (Section 20).

The activities required to implement the capabilities include:

- Operationalise JEN's DVM capabilities at its trial sites of CS and AW, and deploy the DVM technology across its entire network;
- Install tap position-controlled reactors at zone substations to provide available buck taps for DVM to reduce voltage at minimum demand;
- Install interlocked VAr controllers on existing capacitor banks to correctly coordinate with those reactors;
- Undertake traditional network investments to maintain the voltage spread per zone substation within acceptable limits at maximum demand;
- Undertake traditional network investments for the worst-served areas that are not directly resolved by DVM; and
- Continue the recurrent program of works to respond to and resolve customer complaints (consistent with recent historical expenditure levels).

4.5 Data, visibility and analytics program and roadmap

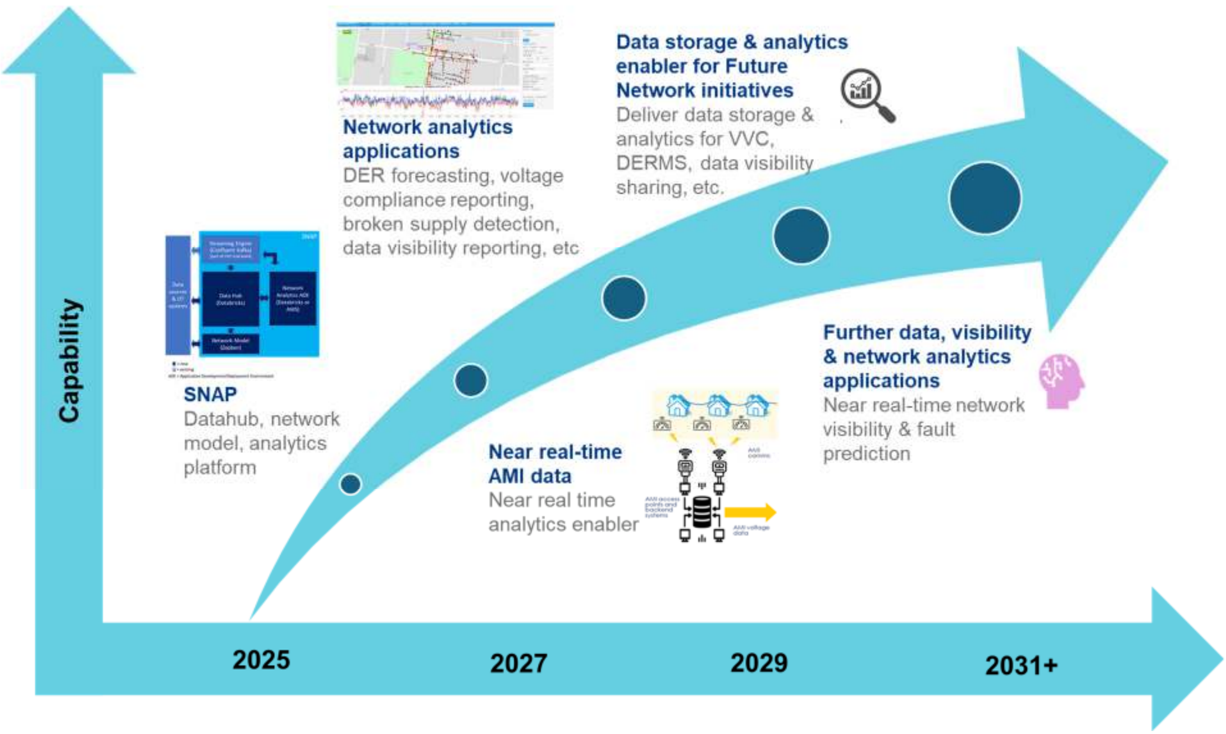
The Data Visibility and Analytics Program articulates the need for further digitalisation of network operations functions using SNAP applications, including applications to simulate new and moved connections, connection approvals, detection of wrong connections, near real-time power quality data for field crews (including predictive analytics), and regulatory data collection obligations.

The goals of this program are to:

- Increase JEN's ability to use network data and analytics to drive operational and planning improvements;
- Position JEN to manage the energy transition and uncertainties ahead by having a flexible and adaptable data and analytics capability; and
- Build foundation data and analytics capabilities once and then use it to support future network analytics initiatives and avoid duplication of capabilities.

The proposed strategic roadmap for the development of JEN's data, visibility and analytics program to meet the identified needs for the next ten years is illustrated in Figure 4.6.

Figure 4.6 – Data Visibility and Analytics Program Roadmap



The activities required to implement the capabilities include:

- Implementing a Strategic Network Analytics Platform (SNAP) that only needs to be built once to support a number of CERIS and broader initiatives instead of building siloed platforms for each initiative;
- Enhancing the smart metering infrastructure to deliver near real-time (5 minutes) smart meter power quality data to enable further operational and safety improvements such as near real-time power quality investigations and predictive fault detection; and

- Implementing a program of network analytics applications to improve operational efficiency and effectiveness, improve safety, and respond to emerging customer and regulatory needs over the next 10 years and beyond.

4.6 Summary of expenditure required from 2023-2031

Our proposed programs are consistent with our customers' expectations for maintaining reliability, automation and connections to CER. Table 4.1 presents the 20-year[18] net economic value of the preferred development program of each of the CER Integration Strategy's subsidiary program roadmaps, based on market benefits.

Table 4.1 – CER Integration Strategy Program Roadmap Economic Evaluation[19]

Economic Evaluation Results	Flexible Services Program[20]	Voltage and Power Quality Management Strategy	Data Visibility and Analytics Program
Present Value Total Costs ($M)	30.8	31.4	25.8
Present Value Benefits ($M)	34.9	33.6	75.6
Net Present Value (NPV) ($M)	4.1	2.2	49.8

All preferred development programs are economically viable based on their estimated costs and market benefits. The key driver for JEN is our regulatory compliance obligations under the:

- Victorian EDCoP for steady-state voltage and quality of supply (Section 20); and
- NER for power system security (Clause 4.3.4(a), Clause 4.3.1(k)(2), and Schedule S5.1.10.1).

18 Benefits held constant at year 10 values for years 11 to 20 of the analysis period.

19 Direct escalated costs (including overheads), June 2024, million dollars.

20 Economic evaluation for distributed UFLS was not conducted, as this is a regulatory compliance requirement.

Table 4.2 presents the total capital and operational expenditure of the preferred development program for each of the CER Integration Strategy's subsidiary program roadmaps.

Table 4.2 – CER Integration Strategy Program Roadmap Total Expenditure ($M, June 2024)[21]

Regulatory Year	Grid Stability and Flexible Services Program	Voltage and Power Quality Management Strategy	Data Visibility and Analytics Program
2026-27	0.7	10.4	5.9
2027-28	3.9	12.1	4.9
2028-29	10.1	10.2	2.5
2029-30	12.4	6.0	2.5
2030-31	8.0	7.9	2.5
Total Cost ($M)	**35.0**	**46.7**	**18.3**

[21] Direct escalated costs capex and opex (including overheads), June 2024, million dollars.

5. Appendix A: Factors affecting the transforming energy market

This appendix sets out emerging challenges that JEN must consider in facilitating the energy market transformation.

JEN is ideally placed to respond to the emerging challenges associated with the energy transformation. JEN has several key strengths that can be leveraged to thrive in the future energy system. These strengths stem from JEN's extensive experience in managing our core assets and our application of big data to improve asset management outcomes, including our:

- **Ubiquitous availability of AMI** – Smart meters, communications and back-end systems are capable of providing control and monitoring capability at the connection point of most of our low-voltage (**LV**) customers. This vast sensing resource minimises the need for LV network modelling assumptions, as actual network operating conditions are available in near real-time.
- **Full coverage of Supervisory Control and Data Acquisition (SCADA)** – SCADA communications and Advanced Distribution Management System (**ADMS**) back-end systems are capable of providing integrated and centralised control and monitoring capability across the high-voltage (**HV**) network.
- **Data analytics platforms** – Digital systems that leverage big data sets (including data from AMI and SCADA) provide the visibility of CER behaviour and its impact on the network's operation, an essential element in addressing the challenges faced by CER. The platforms can facilitate the use of geospatial network analytics and machine-learning applications, ADMS applications, and other operational applications to more efficiently deliver network services in an environment with increasing CER penetration. These digital technology system overlays can allow JEN to optimise the use of its existing network assets, minimising network capital expenditure requirements needed to adapt to the changing energy landscape.

From an organisational perspective, JEN has strengths in:

- **Extensive skills and experience across a diversified energy portfolio** – The broader Jemena group's experience in designing, building, owning and operating both electricity and gas networks and pipelines gives us a broad perspective of Australia's energy system and the transformation that is underway.
- **Growing awareness and focus on customers** – We are recognised by customer advocates as having an advanced awareness of the importance of putting customers at the heart of our activities.
- **Strategic owners with a long-term focus** – As well as JEN benefiting from the corporate disciplines developed under private ownership, our owners have a strategic, rather than purely financial, perspective. This supports long-term vision and decision-making.
- **Access to shareholder intellectual property** – Our shareholders have a wealth of experience, insight and advanced technologies, which we would look to leverage to improve the performance of the asset base and transition to the future energy system.

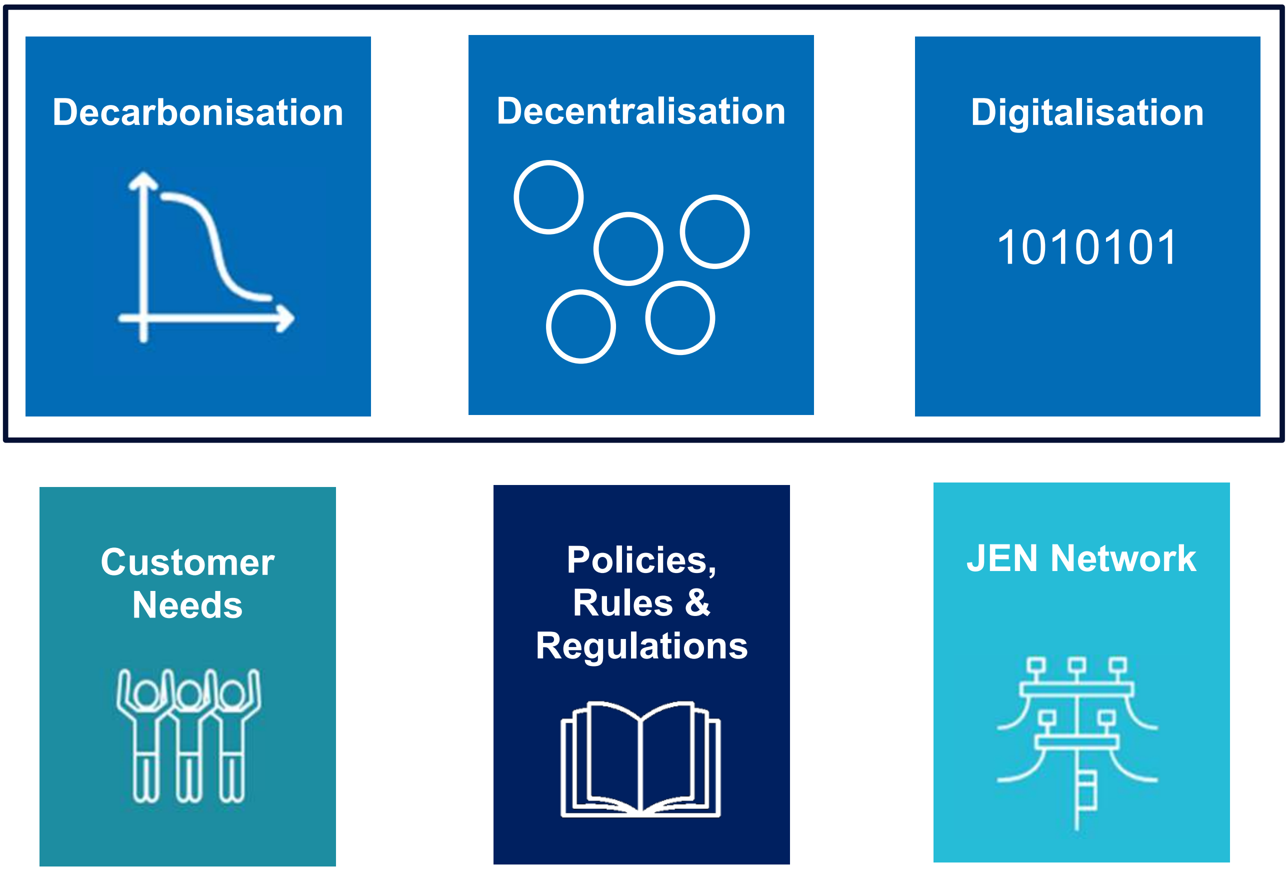
5.1 Megatrends

The global megatrends being observed in the transforming energy market include:

- **Decarbonisation** – a transition from fossil fuels to renewables across all sectors of the economy (including electrification), driven by the need to reduce carbon dioxide emissions for climate change mitigation towards net zero
- **Decentralisation** – a transition from large, centralised generation sources to smaller distributed generation sources, much of which is being installed in the distribution networks within customer premises; and

- **Digitalisation** – exponential growth in the global demand for digital data and the information systems required to support, process and utilise that data, affecting all sectors of the global economy including the energy market.

Figure 5.1 – Global Megatrends



The global megatrends shown in Figure 5.1 are influencing our customer needs and expectations, and informing the development of government policies, rules and regulations, all of which provide the drivers, objectives and frameworks for JEN to adapt its network and help facilitate the energy market transformation.

This section describes each megatrend in detail. The megatrends described here are often interrelated, enabling, amplifying and reinforcing their developments. For example, decarbonisation drives decentralisation, and decentralisation is further enhanced by digitalisation.

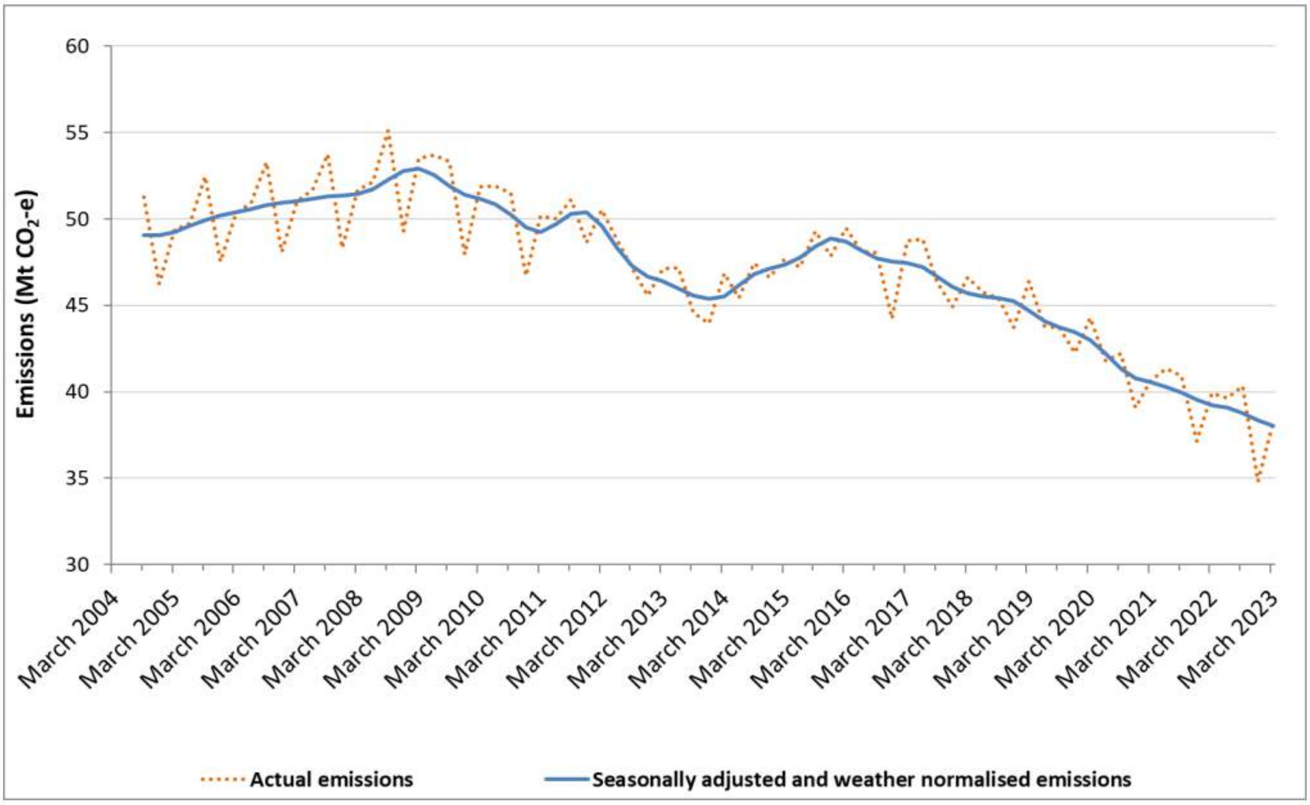
5.1.1 Decarbonisation

The United Nations Framework Convention on Climate Change (**UNFCCC**)[22] Paris Agreement is a legally binding international treaty on climate change. Adopted by 196 countries at the UN Climate Change Conference (**COP21**) in France on 12 December 2015, it entered into force on 4 November 2016. Its overarching goal is to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels" and pursue efforts "to limit the temperature increase to 1.5°C above pre-industrial levels". The Australian Government has ratified the Paris Agreement to target net zero by 2050[23]. Since that time, the total Australian electricity sector emissions have continued their trend downwards as the electricity sector decarbonises as illustrated in Figure 5.2.

22 United Nations, *Framework Convention on Climate Change (UNFCCC)*, 11-24 November 2024.

23 [Australian Government Climate Change commitments, policies and programs (aofm.gov.au)]

Figure 5.2 – Electricity sector emissions, by quarter, September 2004 to March 2023



Source: Quarterly Update of Australia's National Greenhouse Gas Inventory: March 2023, Australian Government (Figure 5)[24]

The COP28 conference held in Dubai in December 2024 marked the conclusion of the first 'global stocktake' of the world's efforts to address climate change under the Paris Agreement. It included a call on governments to speed up the transition away from fossil fuels.

Globally there is growing demand for renewable generation and a shift away from fossil fuels to reduce carbon dioxide emissions to mitigate climate change. Growing demand by customers for lower-cost renewable energy is driving a significant part of the demand for behind-the-meter renewable generation in the form of solar PV panels, which are displacing centralised generation in the National Electricity Market (**NEM**).

Flagged in AEMO's 2023 Electricity Statement of Opportunities (**ESOO**)[25], there are also a large number of expected retirements of thermal generators over the next decade, equating to 20 per cent of the currently registered thermal generation fleet. In Victoria, the 1,600 MW Hazelwood Power Station has already completely retired, and the 1,450 MW Yallourn Power Station is expected to retire in 2028. The retirements are driven by the ageing, unreliable, inflexible and increasingly uncompetitive nature of the coal-fired generation assets. It is likely that significant amounts of variable renewable generation and storage, either large-scale or at the distributed generation level, will enter the electricity system to replace this retiring capacity in anticipation of price rises in the absence of new generation.

The introduction of new renewable generation capacity also triggers a need for greater interconnection of regions and storage to cater to a varying generation mix and the need for new transmission lines to access renewable resource areas. Initiatives currently in progress include actionable transmission projects in Victoria such as VNI [26]West, Western Renewables Link, Marinus Link, Project EnergyConnect, big battery projects, and establishing onshore and offshore renewable energy zones.

[24] Quarterly Update of Australia's National Greenhouse Gas Inventory, DCCEEW, March 2023.

[25] Electricity Statement of Opportunities (ESOO), AEMO, August 2023.

[26] Victoria-NSW Interconnector.

Across all levels of government, there have been and continue to be efforts towards reducing emissions in the electricity sector, as seen through state-based solar feed-in tariffs, energy efficiency schemes, the large-scale Renewable Energy Target, along with various state-based renewable energy targets, and legislated targets. While there remains uncertainty around the policy mechanism to achieve a more ambitious emissions reduction target for the electricity sector, there is consensus among the public and industry that Australia's electricity sector will have to decarbonise faster than other sectors for Australia to meet its commitment to the Paris Agreement, due to the sector being the most significant contributor to total emissions. There is also consensus that to meet the decarbonisation targets, electrification of gas and transport will be required, further strengthening the need to decarbonise the electricity system.

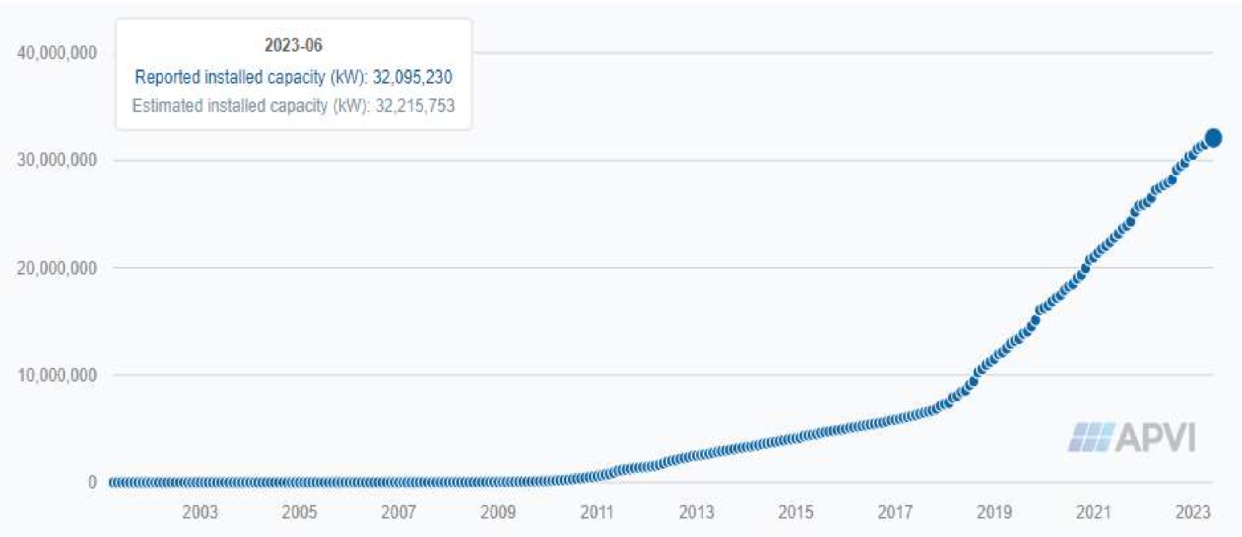
5.1.2 Decentralisation

Energy generation and storage is becoming more decentralised. In the last decade, there has been a gradual decline in demand for centrally-supplied electricity. Simultaneously, the generation from and consumption of electricity from distributed, behind-the-meter sources have increased. These CERs are, by definition, decentralised in their geographic location, ownership status and operational profiles.

They are directly connected to a local distribution system or connected to customer premises within the local distribution system. They can be integrated either as a passive or active player in the power system by exporting energy into the grid when there is a surplus of local generation or through control of their output either in isolation or in aggregate via a Virtual Power Plant (**VPP**).

The various forms of decentralised energy include solar PV panels, wind generators, combined heat and power plants, electricity storage systems, small natural gas-fuelled generators, diesel generators, EVs (as load and generation) and controllable loads, such as industrial loads, HVAC systems and electric water heaters. This shift towards decentralisation is driven by customer interest in renewables and energy cost savings. The total installed capacity of solar PV in Australia, according to the Australian PV Institute (**APVI**)[27] in Figure 5.3, has now reached 32 GW (3.52 million installations).

Figure 5.3 – Solar PV installed capacity in Australia by year



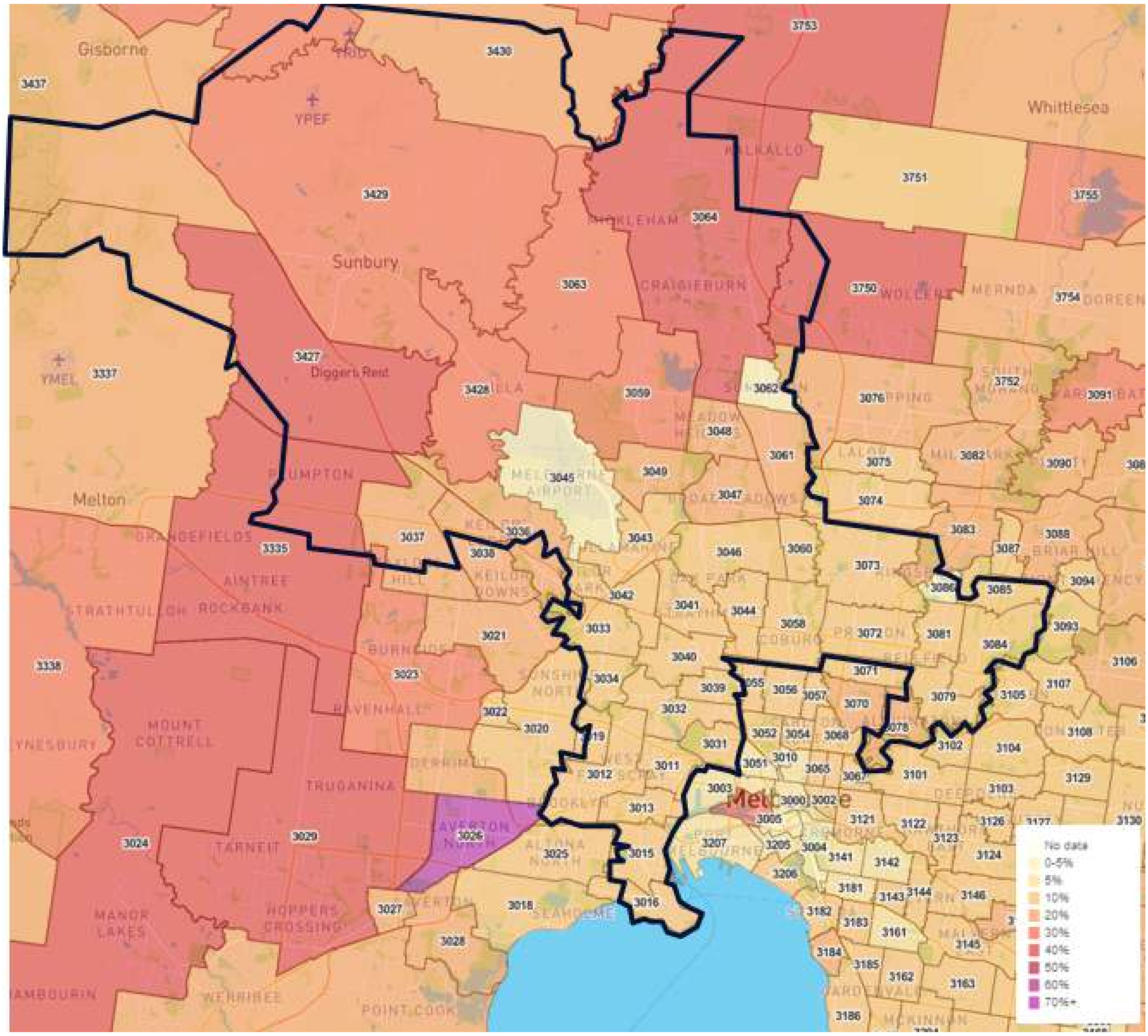
Source: Australian PV Institute (APVI)

The growth in distributed solar PV connections has continued strongly in the last 15 years. Data from the APVI[28] indicates that the penetration of distributed solar PV in Victoria, measured by the number of installations as a proportion of total households, grew to around 26% in 2023. The penetration by postcode in JEN's service area is illustrated in Figure 5.4, with the outer fringes of the metropolitan area recording the highest penetrations.

[27] Market Analyses, Australian Photovoltaic Institute (APVI), October 2023.

[28] Mapping Australian Photovoltaic installations, Australian Photovoltaic Institute (APVI), October 2023.

Figure 5.4 – Solar PV penetration in north-western Melbourne by postcode (October 2023)



Source: Australian PV Institute (APVI)

5.1.3 Digitalisation

There has been a proliferation of digital technologies across most aspects of the economy over the last couple of decades. The digitalisation of the energy sector and the increasing availability of digital standing and sensing data—and the systems able to process that data—are expanding the range of data and technology solution opportunities available. The future of the energy sector is centred around big data and analytics, machine learning and predictive capabilities to manage network health, customer needs and optimised ways of working. In the electricity system, digital technologies have enabled devices across the electricity network to communicate and share data that might be useful for customers and grid management or operation. For example:

- big data analytics allows distributed energy management through advanced planning and operational applications, facilitated by network sensors and smart meters

- asset management strategies based on big data predictive analysis (machine learning) allow asset condition monitoring and optimisation, and lifecycle extension
- smart grid solutions (energy storage, internet of things (IoT), flexible management, automation, etc.) can be used to improve network performance and efficiency and improve choice and services for customers
- customer analysis made possible by smart meters and big data allows demand response management and other enhanced distribution services
- availability of data and systems to facilitate market services for market service providers
- automation of processes and enhanced data support for better and streamlined decision-making
- workforce optimisation through better access to information, routing optimisation and optimised resource allocation; and
- better knowledge of the current and forecast operational status of the network, for improved operational management of the network.

The benefits of digitalisation in the energy sector indicate that operators who are late adopters are likely to be left behind, as they have less knowledge of their customers, poorer management of their workforces and assets, and are less prepared for future network changes.

5.2 Changing market rules, policies, and regulations

5.2.1 Commonwealth Government policy

Australian emission reduction policies are legislated in the Climate Change Act (2022) with emission reduction targets of 43% below 2005 levels by 2030 and net zero by 2050. Australia's Climate Change Act acts as 'umbrella' legislation for greenhouse gas reduction targets. Key policies and programs include the:

- Powering Australia Plan[29] to support the decarbonisation of electricity generation and the uptake of EVs, with a commitment by the Commonwealth Government for renewable generation to achieve an 82 per cent share of renewable generation by 2030; and
- Safeguard Mechanism[30] (in place since 2016 with reforms in 2023) to drive business and industrial emissions reduction for facilities emitting more than 100,000 tonnes of carbon dioxide equivalent (CO2-e) per year.

The Energy Security Board's (**ESB**) Post 2025 Electricity Market Design[31] envisaged reforms that impact the functions and role that distributors have in the NEM to facilitate the transformation of the energy market to meet the Commonwealth's policy objectives for decarbonisation and renewable generation. This includes areas of reform regarding CER integration, data strategy and essential system services (including power system security and voltage).

The ESB has since been disbanded and replaced by an Energy Advisory Panel from 1 July 2023 to coordinate market body advice to governments from the Australian Energy Market Operator (**AEMO**), Australian Energy Regulator (**AER**) and Australian Energy Market Commission (**AEMC**), with the Australian Competition and Consumer Commission (**ACCC**) Energy Commissioner acting as an observer. Commonwealth, state and territory ministers and government departments are now collectively responsible for developing energy policy.

In 2023, the NEO and NEL was updated to include consideration of reducing greenhouse gas emissions targets set by jurisdictions (point c below):

29 Powering Australia Plan, Commonwealth of Australia, 2023.

30 Safeguard Mechanism – DCCEEW, 2023.

31 Post 2025 electricity market design project - Energy Security Board (ESB).

The NEO is to promote efficient investment in, and efficient operation and use of, electricity services for the long-term interests of consumers of electricity with respect to:

a) price, quality, safety, reliability and security of supply of electricity; and

b) the reliability, safety and security of the national electricity system; and

c) the achievement of targets set by a participating jurisdiction—

   i) for reducing Australia's greenhouse gas emissions; or

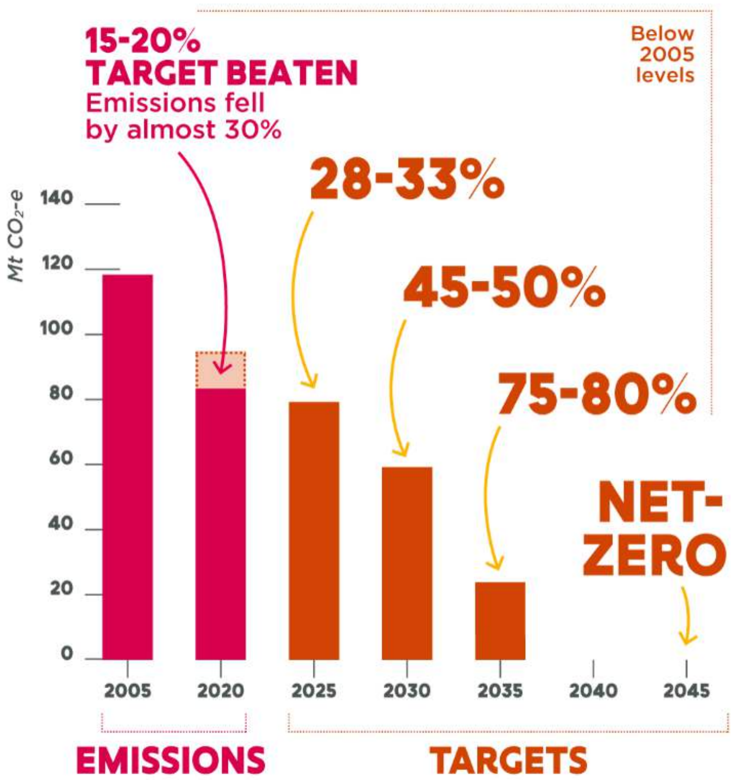
   ii) that are likely to contribute to reducing Australia's greenhouse gas emissions.

In developing our strategy, we are giving consideration to the recent amendments that focus on reducing greenhouse gas emissions. This is also considered to be important by our customers who told us to play an active role in addressing environmental considerations.

5.2.2 Victorian Government policy

Victorian Government emission reduction policies are legislated in Victoria's Climate Change Act (2017)[32]. In October 2022, new more ambitious emission reduction targets were set, as shown in Figure 5.5, with targets of 28-33% below 2005 levels by 2025, 45-50% by 2030, 75-80% by 2035 and net-zero by 2045[33]. The government legislated these more ambitious targets in March 2024.

Figure 5.5 – Victorian government emissions targets



Source: Victorian Government

Apart from the emission reduction targets, Victoria has a suite of energy-related programs and roadmaps supporting the achievement of those targets, including Solar Homes[34] to support the uptake of rooftop solar PV

32 Climate Change Act 2017, Victorian Government.

33 Climate action targets, Victorian Government, 2023.

34 Solar Homes Program, Solar Victoria, 2023.

and other programs delivered through Solar Victoria, the Zero Emissions Vehicles Roadmap[35], and the Gas Substitution Roadmap[36].

- Solar Homes is a consumer rebate program for household solar PV installations, batteries and hot water systems. The program has been operating for several years, with solar PV rebates being consistently oversubscribed throughout the program's life to date. The Zero Emissions Vehicles Roadmap released in May 2021 presents a set of policies and programs that aim for half of light vehicle sales in Victoria to be zero-emission vehicles by 2030. The Gas Substitution Roadmap was released in October 2022 and outlines options for replacing gas usage (such as energy efficiency, electrification, hydrogen and biogas) to reduce emissions and consumer costs.
- The Victorian Government has a Victorian Renewable Energy Target (**VRET**) of 40% by 2025 for renewable generation, 50% by 2030 under the Renewable Energy (Jobs and Investment) Act 2017[37], and has intentions to update VRET with 65% of the state's generation to come from variable renewable energy by 2030 and 95% by 2035.
- Victoria has pending legislation for energy storage targets of 2.6 GW by 2030 and 6.3 GW by 2035, and for offshore wind of 2 GW by 2032, 4 GW by 2035, and 9 GW by 2040 as stated in its Offshore Wind Policy Directions Paper[38].
- The Victorian Energy Upgrades (**VEU**) program[39] is the appliance upgrade for energy efficiency improvements comprising Victorian Energy Efficiency Certificates.

5.3 Changing customer needs

Increasingly competitive markets and offerings are giving consumers a broader range of choices. Markets are also increasingly emphasising customer centricity. The megatrends described above are resulting in technological developments that change how customers can interact with the electricity system, either through energy retailers, independent aggregators or directly with networks. In recent years, there has been an increase in customers who are shifting from a passive relationship with the electricity system into one where they more actively manage their use of energy.

Besides technological developments such as home energy management systems, solar panels and battery storage, which allow customers to engage with their energy retailers and networks, other factors have contributed to this shift in consumer attitude. These include rapidly falling CER installation costs at the residential level, significantly improving the payback period of customer investments, and rising electricity prices that further improve the attractiveness of these investments.

New products and services are emerging that allow customers to generate and store their electricity, and more importantly, allow them to manage their energy use. For example, residential customers with a home energy management system and storage can become actively involved in modifying their energy expenditure by monitoring their actual consumption in real-time. Market innovations can also provide energy consumers with greater variety and choice in how they purchase energy services. These changing dynamics between consumers and the electricity system will continue to evolve with the availability and continued uptake of enabling technologies such as solar PV, battery storage and smart grids.

Besides active CER customers who manage their energy bills, some passive customers do not or cannot seek to invest in CER. As a result, either by choice or circumstance, some customers will continue to use the network traditionally and will not be involved in this customer shift. In practice, customer groups are much more complex than these two categories, and as such JEN considers a range of customer segmentations based on distinct patterns of customer engagement and behavioural traits.

35 Zero Emissions Vehicles Roadmap, DEECA, 2021.

36 Gas Substitution Roadmap, DEECA, 2023.

37 Renewable Energy (Jobs and Investment) Act 2017, Victorian Government.

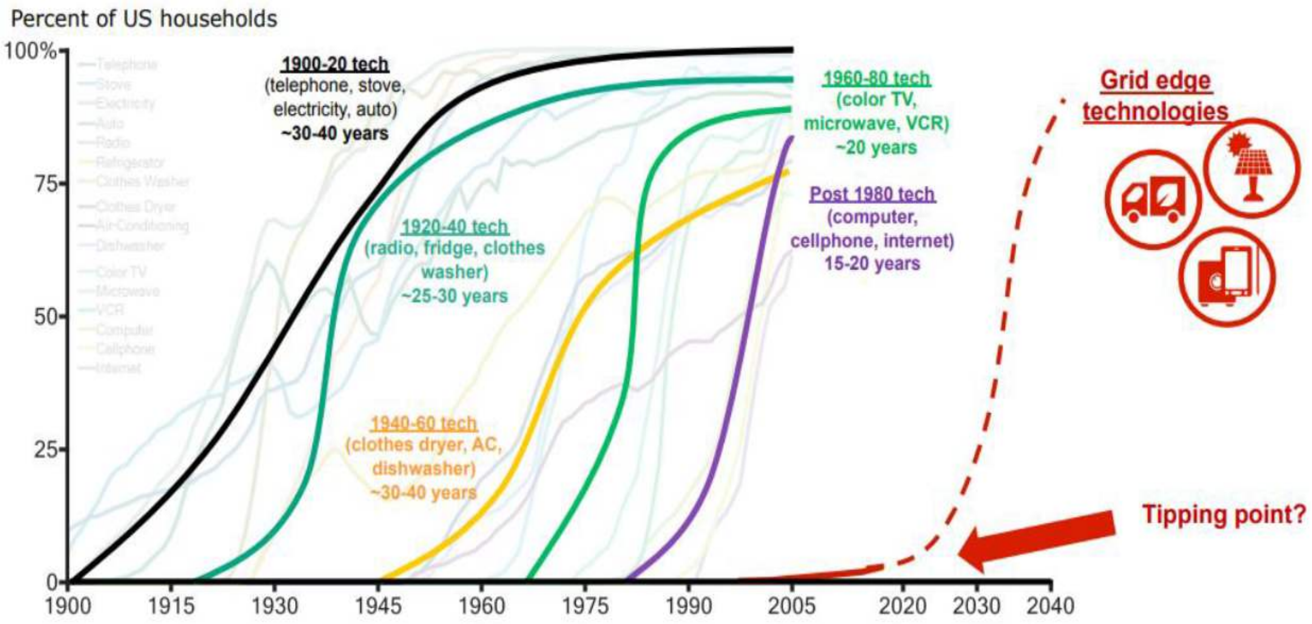
38 Offshore Wind Policy Directions Paper, Victorian Government, March 2022.

39 Victorian Energy Upgrades program, DEECA, 2023.

5.3.1 Solar PV

CER technology costs are falling rapidly. Consumer adoption of these technologies is expected to follow the same S-curve[40] as other new technologies such as air-conditioners, home electronic appliances, smartphones, computers and the internet.

Figure 5.6 – Time for new technologies to reach 80% penetration (S-Curve)



Source: The Future of Electricity – New Technologies Transforming the Grid Edge, World Economic Forum, March 2017[41]

While the tipping point for these new technologies is difficult to predict, the adoption of distributed solar PV is well past its tipping point, which occurred back in 2009, and is now mature along the S-curve with more than 25% of households having a rooftop solar PV system after 14 years in the mass market. Customers have accepted solar PV as a credible and cost-effective way to reduce their carbon footprint and reduce their electricity bills. Growth in distributed solar PV installed capacity is expected to remain strong for the foreseeable future.

5.3.2 Storage

Low-cost electricity storage could fundamentally change the electricity system. The electricity system was designed to deliver electricity from generation points to end users while ensuring demand for and supply of electricity is met instantaneously, as electricity cannot easily be stored. This need was driven by the lack of technologically and economically feasible forms of electricity storage.

There is still huge uncertainty around when standalone distributed storage technologies will reach a tipping point and have not yet been widely accepted by consumers to date. The economics of storage remain heavily influenced by relevant government policies and financial incentives, and at present with the cost premium required and long payback periods for standalone distributed battery storage systems, there is significant uncertainty as to when or if these tipping points might be reached.

Despite the relatively low uptake of distributed storage in the household market, standalone storage is becoming more commonplace in the transmission sector with its potential to provide system security and frequency control-type services, and also at the community battery system level within the distribution networks where it can easily be aggregated into VPPs.

---

40 The typical take-up profile over time of new technology that becomes accepted by consumers.

41 The Future of Electricity – New Technologies Transforming the Grid Edge, World Economic Forum, March 2017.

5.3.3 Electrification of transport

EV sales have increased in Australia recently. EVs reached their tipping point in around 2021-22 as battery-only and plug-in hybrid electric vehicles combined reached over 9% of new vehicle sales in Australia in Q2 2023[42]. This compares with only 2% a year earlier and less than 1% before that. This trend is consistent across all Australian states.

The outlook for residential EVs points towards mass uptake in Victoria this decade, enabled by decreasing upfront capital costs, improved battery technology safety and capability, increasing availability of charging infrastructure, and a larger range of vehicle models available for sale. Business customers, particularly logistics and public transport businesses, are also shifting towards electrifying their fleets as they move towards net zero.

5.3.4 Electrification of gas

With the introduction of high levels of renewables in the electricity system, a foreseeable outcome from this decarbonisation megatrend is the electrification of other fossil-fuelled activities, including reticulated gas. Victoria has the largest potential for residential electrification, due to its current high level of gas use for residential heating. 92% of homes in Greater Melbourne are currently connected to the gas network (75% for all of Victoria).

Until recently, all new Victorian homes were required to have a gas connection. In line with the Gas Substitution Roadmap[43], the Victoria Planning Provisions will be changed to remove the gas connection requirement in new residential subdivisions. Additional incentive programs are included in the Gas Substitution Roadmap including for hot water or electric heating and cooling units, and 7-star efficiency standards for new homes. Business customers are also increasingly moving towards electrification away from gas to help achieve net zero targets.

5.3.5 Demand for electricity

Growth in demand for electricity is influenced by population and economic growth. Electrification of transport and gas could also lead to a significant increase in aggregate demand for electricity, if not carefully managed. High inflation rates and consecutive cash rate rises over the past year, coupled with relatively low consumer confidence and expected wind-backs in government expenditure, suggest that the economy is headed for a potential recession in the near term. This will dampen growth in demand for electricity with any growth in the short term driven primarily by population growth.

Any economic downturn that may materialise may be short-lived, with growth in electricity demand returning to more moderate levels over the medium to long term, driven by population growth, business growth, and the accelerated electrification of the energy system. This will be particularly valid for the JEN with the network being located in a high residential construction growth corridor, with a population expected to grow by 50% by 2036 in north and west Melbourne. This region serviced by JEN is expected to drive Victoria's economic growth in the medium to long term. The Victorian economy is forecast to grow by 2.2% p.a. over the next 10 years.

North-west Melbourne has been identified as an industrial growth corridor by the Victorian Government. With available and affordable land relative to other areas of metropolitan Melbourne, and existing manufacturing capabilities, it is an attractive location for further industrial development, including data centre facilities. Opportunities for business commercial and industrial development in JEN's service area within the north-west metropolitan Melbourne region include:

- **Healthcare and biotechnology**: Victoria has seen an increase in investment in hospitals, especially in high-growth areas in the north and west of Melbourne. Healthcare hubs have also been a target of investment with more hospitals to accommodate population growth. Healthcare services (including aged care and retirement facilities) will need scale to meet the challenges of the growing and aging population in Melbourne's north and west, particularly given the region's lower socio-economic. Examples include the [redacted]

42 EV Index - Data Dashboard, Australian Automobile Association (AAA), 2023.

43 Victoria's Gas Substitution Roadmap (energy.vic.gov.au)

44 Global Biotechnology Company | CSL

- **Food and beverage**: The Victorian Government has previously given grants to small food companies to accelerate their growth, alongside expressing sentiment about north-west Melbourne becoming a food 'hub', as well as establishing a major wholesale fruit, vegetable and flower market in Epping. Examples include the [redacted]

- **Advanced manufacturing**: The region contributes significantly to the state and national economy from its traditional manufacturing and heavy industry base (e.g., food manufacturing and pharmaceutical production). Advanced manufacturing is the evolution of traditional manufacturing to include innovative technologies (e.g., automation, 3D printing). The Victorian Government and local councils have expressed support, especially in certain sectors such as composites and advanced materials, food additives, and biotechnology. There is strong momentum across the region to move towards an advanced manufacturing and knowledge-based industry focus. Notable projects to enable this transformation within the JEN network include the revitalisation of the Broadmeadows Town Centre, which includes a new Advanced Manufacturing Centre for Assistive Technology, [redacted].

- **Freight and transport**: The region has an attractive and effective freight network, with close access to Melbourne Airport, Essendon Airport and the Port of Melbourne. Several large freight-based projects are in development or the planning phase. This serves to increase the number of jobs available in the north and west of Melbourne and relieve pressure on other busy freight corridors. Examples include the Beveridge Intermodal Freight Terminal, and Western Interstate Freight Terminal (Truganina) (**WIFT**). A significant proportion of residents and workers in north-west Melbourne commute two hours or more daily. A lack of integrated transport options, particularly to employment hubs such as the La Trobe National Employment & Innovation Cluster, increases traffic congestion and commuting times. Improved transport and connectivity will provide better access to industry, employment, health, and education and increase overall liveability. Several major projects currently under construction will increase connectivity and public transport utilisation. These include the Melbourne Airport Rail Link, Suburban Rail Loop, and North-East Link.

- **Education**: The rapidly growing population of the region is creating unprecedented and unmet demand for educational institutions (i.e., from early childhood to at-risk teens, new migrants, etc). Key projects to fill this need within the region include the [redacted], which will serve as major health education precincts.

- **Data centres**: Over the last five years, cloud services have emerged as a new driving force for Australian businesses. Cloud services are changing business models and are a foundational technology that seeks to unlock the next wave of technologies (e.g., artificial intelligence and blockchain). As cloud adoption continues to grow, along with the need to store customer data within Australia, demand for data centres will follow suit. JEN has already had numerous enquiries and new connections for new data centre connections within its service area over the last couple of years.[45]

5.4 Challenges – impacts and consequences

With the energy system transformation and the associated impact of CER uptake and electrification, distributors will be faced with significant challenges in maintaining network reliability, power system security, and quality of supply to continue to meet regulatory requirements and changing customer needs.

Increasing penetration of unmanaged CER can lead to a range of technical issues for electricity networks. For example, high levels of rooftop solar PV exporting to the network can result in voltage rises if the network is not upgraded, especially during peak solar generation in the middle of mild sunny days. This presents voltage compliance issues for distributors and solar PV generation curtailment. Solar PV export at this time also presents power system security challenges for AEMO, which need to be managed collectively by the distributors. Large power exports and imports by customers can present reliability issues, when networks face the risk of asset thermal overload in the absence of a distribution network capacity upgrade.

To minimise the risk of needing to make large investments in network infrastructure augmentations to address the challenges, an alternative is to better manage CER with improved visibility and control. By providing the right incentives to customers or intermediaries, networks should be able to adopt less capital-intensive solutions while

[45] Further details on data centre growth in JEN's distribution area can be found in attachment 05-01.

delivering value to customers. The ability for networks to implement enhanced pricing signals plays an important role in incentivising customers' behaviour, capturing the benefits of CER and facilitating electrification.

5.4.1 Transmission challenges impacting distribution

JEN is registered with AEMO as a Distribution Network Service Provider (**DNSP**) in the NEM and holds an electricity distribution licence in Victoria. This places specific obligations on JEN to plan, operate and maintain its network in accordance with relevant statutory codes and rules. AEMO has primary responsibility for system security under Clause 4.3.1 of the NER. However, there is a general obligation on DNSPs under Clause 4.3.4(a) of the NER to respond to AEMO's direction by developing and implementing solutions to mitigate power system security risks at AEMO's direction.

AEMO is responsible for dispatching generation in the NEM to maintain supply-demand balance and historically networks are responsible for disconnecting load at transmission terminal stations in response to under-frequency events. This approach to setting responsibilities made sense when most generation was large, centralised, controllable and connected to the transmission networks, and when transmission points of connection were always net loads.

With significant growth in distributed embedded generation, much of which is uncontrolled DPV, solutions at the transmission level are becoming increasingly ineffective, as transmission points of connection (at times) transition from net loads to net generators.

AEMO expects that net minimum demand in Victoria to fall below its minimum acceptable operating threshold is imminent. This poses challenges for AEMO in its role in maintaining power system security, for two key stability elements and their consequences. Actions are required to redress both of these emerging power system security needs. These actions are needed in the form of granular solutions at the distribution level to redress the associated power system security issues that are forecast in Victoria over the coming years.

As such, in August 2021, AEMO issued a directive[46] to JEN and other Victorian network businesses, asking network service providers to identify and implement measures to restore power system security from the challenges caused by increasing levels of uncontrolled DPV within their respective networks. The two key stability elements of concern to AEMO are supply-demand balance (minimum demand), and under-frequency load shedding (**UFLS**) scheme, and are detailed below.

5.4.1.1 Supply-demand balance

The supply-demand balance system security challenge occurs when the net minimum system demand (as seen at the transmission level) falls below a level that will compromise the stability of the overall power system. It manifests as an oversupply of DPV generation that cannot be controlled by AEMO, causing the power system to collapse due to the system frequency rising well above 50 Hz due to generation exceeding demand. This tends to follow a critical contingency event such as the loss of an interconnector, eventually emerging into a system-normal event as DPV continues to grow.

5.4.1.2 UFLS

UFLS is an existing load-shedding control scheme triggered upon a loss of generation event that becomes ineffective due to the presence of reverse power flows from DPV, causing the power system to collapse due to the system frequency falling well below 50 Hz due to demand exceeding generation.

UFLS schemes were traditionally designed on the assumption that they would shed blocks of load based on one-way power flow. With the uptake of DPV, there is an increasing risk of the load-shed blocks being net negative (i.e., generation) sources because of reverse power flows. The effect of shedding such blocks can cause a state-wide collapse of the power system from under-frequency.

NER schedule S5.1.10.1 and clause 4.3.1(k) require NSPs to ensure that 60% of underlying load is under the control of the UFLS scheme, as measured by the net demand at transmission connection points. This will become

46 AEMO letter to JEN dated 9 August 2021.

increasingly difficult as DPV growth continues and the net demand as measured by the UFLS scheme reduces. Load blocks with reverse power flow and the reduced numbers of available load blocks are a threat to the effectiveness of the UFLS scheme in responding to a widespread loss of transmission generation sources.

AEMO and DEECA require DNSPs to implement a distributed, granular UFLS control scheme that involves the automatic disconnection of dynamic load blocks through the ability to apply settings remotely (i.e., frequency and trip time), monitor, arming and disarming of UFLS, disconnect (in 0.2-0.5s response time), and restore load within the distribution network.

5.4.2 Distribution challenges

Network thermal capacity and network design limits for voltage have traditionally been set based on maximum demand conditions where power is assumed to be flowing at its maximum in the forward direction towards the load. Voltage drop assumptions caused by the maximum demand are designed into the network to cater for the discrete nature of voltage regulation equipment located upstream at the HV zone substations.

The uptake of DPV and other forms of CER is causing power to flow upstream in the reverse direction. Therefore, the traditional design assumptions around voltage regulation and capacity are now being challenged. The following section presents the voltage and thermal-related challenges that JEN faces due to higher CER levels in the network.

5.4.2.1 Voltage

JEN is required to comply with the steady-state voltage and quality of supply requirements at its customer connection points, prescribed by the Essential Services Commission (**ESC**) of Victoria's EDCoP[47], Section 20. For LV, where the bulk of JEN's customers are connected, steady-state voltages at each connection point must be maintained within the limits of 216V (i.e., 230V - 6%) and 253V (i.e., 230V +10%), for 99% of the time. For HV urban customers, this tightens to ±6% for 100% of the time.

The network is traditionally designed for maximum demand conditions that occur infrequently during the year on days of extreme ambient temperatures. On all other days of the year, customer voltages tend to regulate towards the upper end of the EDCoP regulatory limits. As such, power exported at customer connection points by installed CER causes voltages to rise in parts of the network closest to the CER, potentially raising voltages of that connection point (and/or those around it) above EDCoP regulatory upper limits.

Under such conditions, the HV voltage regulation equipment installed higher up in the network may not detect such voltage rises occurring within the LV networks and therefore, not restore the voltages within the allowable regulatory range. When larger clusters of CER emerge, this voltage rise can propagate further up into the network, but voltage regulation equipment may not be able to bring down the voltage to within regulatory limits if the transformers run out of available taps (particularly as many legacy transformers have limited buck tap capability).

Apart from the regulatory non-compliance issues that arise from this effect, the elevated voltages may also trigger an increase in customer complaints and claims for equipment damage, increase customer consumption, and cause DPV inverters to either trip[48], curtail power output[49], or absorb reactive power[50]. This can have a direct impact on customer bills with potentially increased consumption costs and/or lower feed-in tariff payments. Essentially all of JEN's challenges regarding CER export relate to voltage and this is expected to remain the case over the next several regulatory control periods.

5.4.2.2 Thermal

When DPV penetration is high, reverse power flows caused by DPV export could exceed the thermal capacity of the asset, causing an overload. The export thermal capacity of a network asset is generally the same as its forward

47 ESC, *Electricity Distribution Code of Practice Version 2*,1st May 2023.

48 255 V trip for legacy inverters, 258 V for smart inverters.

49 Output curtailed above 253 V.

50 Reactive power absorption commences above 241V for smart inverters only.

power flow import thermal capacity, but some exceptions apply on JEN’s network, particularly for some types of zone substation transformers with certain on-load tap changers that limit the reverse power rating to only 30% of the forward power flow capacity.

There are very few instances where CER export triggers thermal limitations because DPV penetration levels need to be high enough to overcome the local load to generate material levels of export through the network asset to create the network limitation. This is expected to remain the case on the JEN network over the next several regulatory control periods, with voltage being the dominant limitation.

6. Appendix B: programs of work that support JEN's CER Integration Strategy

The following tables provide a breakdown of the projects which make up the programs of work, supporting JEN's CER Integration Strategy.

6.1 Voltage and power quality management

					Total escalated costs (excl. type 2 capcons) ($'000s June 2024)					
Cost type	**CER Strategy**	**Project name**	**Unique ID**	**Cost**	**2026-27**	**2027-28**	**2028-29**	**2029-30**	**2030-31**	**Totex**
ICT	VVC & PQ	VVC (Volt Var Control) rollout	A983	Capex	$ 124					**$ 124**
ICT	VVC & PQ	VVC (Volt Var Control) rollout	A983	Step Opex	$ 630	$ 580	$ 580	$ 580	$ 580	**$ 2,950**
Network	VVC & PQ	VVC rollout	A286	Capex	$ 7,065	$ 7,003	$ 4,434			**$ 18,502**
Network	VVC & PQ	VVC (Volt Var Control) rollout	A286	Step Opex	$ 200	$ 200	$ 200	$ 200	$ 200	**$ 1,000**
Network	VVC & PQ	Install reactors at BD - 4 x 4MVAr reactors, two off 2 x 4MVAr capacitor banks	A370	Capex					$ 2,424	**$ 2,424**
Network	VVC & PQ	Install reactors at ST - 2 x 4MVAr	A74	Capex				$ 708	$ 1,451	**$ 2,159**
Network	VVC & PQ	Install reactors at SBY - 2 x 4MVAr	A75	Capex	$ 575	$ 1,158	$ 584			**$ 2,317**
Network	VVC & PQ	Install reactors at SHM - 2 x 4MVAr	A76	Capex		$ 642	$ 1,295	$ 657		**$ 2,595**
Network	VVC & PQ	Future Grid - Hosting Capacity (LV Network)	A564	Capex	$ 121	$ 122	$ 123	$ 124	$ 127	**$ 616**
Network	VVC & PQ	Install reactors at COO - 2 x 4MVAr	A369	Capex			$ 655	$ 1,328	$ 680	**$ 2,662**
Network	VVC & PQ	Interlocked VAr controllers on 14 existing capacitor banks	A471	Capex	$ 322	$ 648	$ 653	$ 663	$ 679	**$ 2,965**
Network	VVC & PQ	Distribution substation augmentation - supply quality	A111	Capex	$ 1,378	$ 1,708	$ 1,720	$ 1,743	$ 1,784	**$ 8,333**
				Totex	**$ 10,414**	**$ 12,062**	**$ 10,244**	**$ 6,003**	**$ 7,924**	**$ 46,648**

6.2 Grid stability and flexible services program

					Total escalated costs (excl. type 2 capcons) ($'000s June 2024)					
Cost type	CER Strategy	Project name	Unique I	Cost	2026-27	2027-28	2028-29	2029-30	2030-31	Totex
ICT	Grid Stability	Foundational Distributed UFLS (Underfrequency Load Shedding) Capabilities	A736	Capex	$ 345	$ 706	$ 495	$ 269	$ 148	**$ 1,962**
ICT	Grid Stability	Flexible exports	A240	Capex		$ 2,443	$ 7,086	$ 4,675		**$ 14,204**
ICT	Grid Stability	Flexible exports	A240	Step Opex			$ 1,049	$ 1,299	$ 502	**$ 2,850**
ICT	Grid Stability	Flexible imports	A738	Capex				$ 4,044	$ 6,053	**$ 10,097**
Network	Grid Stability	Brooklyn Terminal Station UFLS - Network	A475	Capex	$ -	$ 394	$ 397	$ -	$ -	**$ 790**
Network	Grid Stability	Brunswick Terminal Station UFLS - Network + New Development	A476	Capex	$ 314	$ 317	$ -	$ -	$ -	**$ 631**
Network	Grid Stability	Keilor Terminal Station UFLS - Network	A478	Capex			$ 781	$ 792		**$ 1,574**
Network	Grid Stability	South Morang Terminal Station UFLS - Network	A479	Capex				$ 108	$ 110	**$ 218**
Network	Grid Stability	Templestowe Terminal Station UFLS - Network	A482	Capex					$ 90	**$ 90**
Network	Grid Stability	Thomastown Terminal Station UFLS - Network	A484	Capex				$ 882	$ 903	**$ 1,785**
Network	Grid Stability	West Melbourne Terminal Station UFLS - Network	A485	Capex			$ 202	$ 205		**$ 407**
Network	Grid Stability	FN - Flexible exports	A240	Step Opex			$ 87	$ 175	$ 175	**$ 437**
				Totex	**$ 659**	**$ 3,859**	**$ 10,097**	**$ 12,449**	**$ 7,980**	**$ 35,044**

6.3 Data, visibility and analytics program

					Total escalated costs (excl. type 2 capcons) ($'000s June 2024)					
Cost type	**CER Strategy**	**Project name**	**Unique ID**	**Cost**	**2026-27**	**2027-28**	**2028-29**	**2029-30**	**2030-31**	**Totex**
ICT	Analytics Program	Strategic Network Analytics Platform (SNAP) - Data Hub	A742	Capex	$ 1,435					**$ 1,435**
ICT	Analytics Program	Strategic Network Analytics Platform (SNAP) - Data Hub	A742	Propex	$ 252					**$ 252**
ICT	Analytics Program	Strategic Network Analytics Platform (SNAP) - Data Hub	A742	Step Opex		$ 325	$ 325	$ 325	$ 325	**$ 1,300**
ICT	Analytics Program	Network Analytics Program	A743	Capex	$ 1,678	$ 1,693	$ 1,710	$ 1,731	$ 1,751	**$ 8,562**
ICT	Analytics Program	Network Analytics Program	A743	Propex	$ 125	$ 125	$ 125	$ 125	$ 125	**$ 625**
Network	Analytics Program	Strategic Network Analytics Platform (SNAP) - Data Hub	A742	Step Opex		$ 350	$ 350	$ 350	$ 350	**$ 1,400**
Network	Analytics Program	AMI Near real time data		Capex	$ 2,386	$ 2,386				**$ 4,773**
				Totex	**$ 5,877**	**$ 4,879**	**$ 2,510**	**$ 2,531**	**$ 2,551**	**$ 18,347**