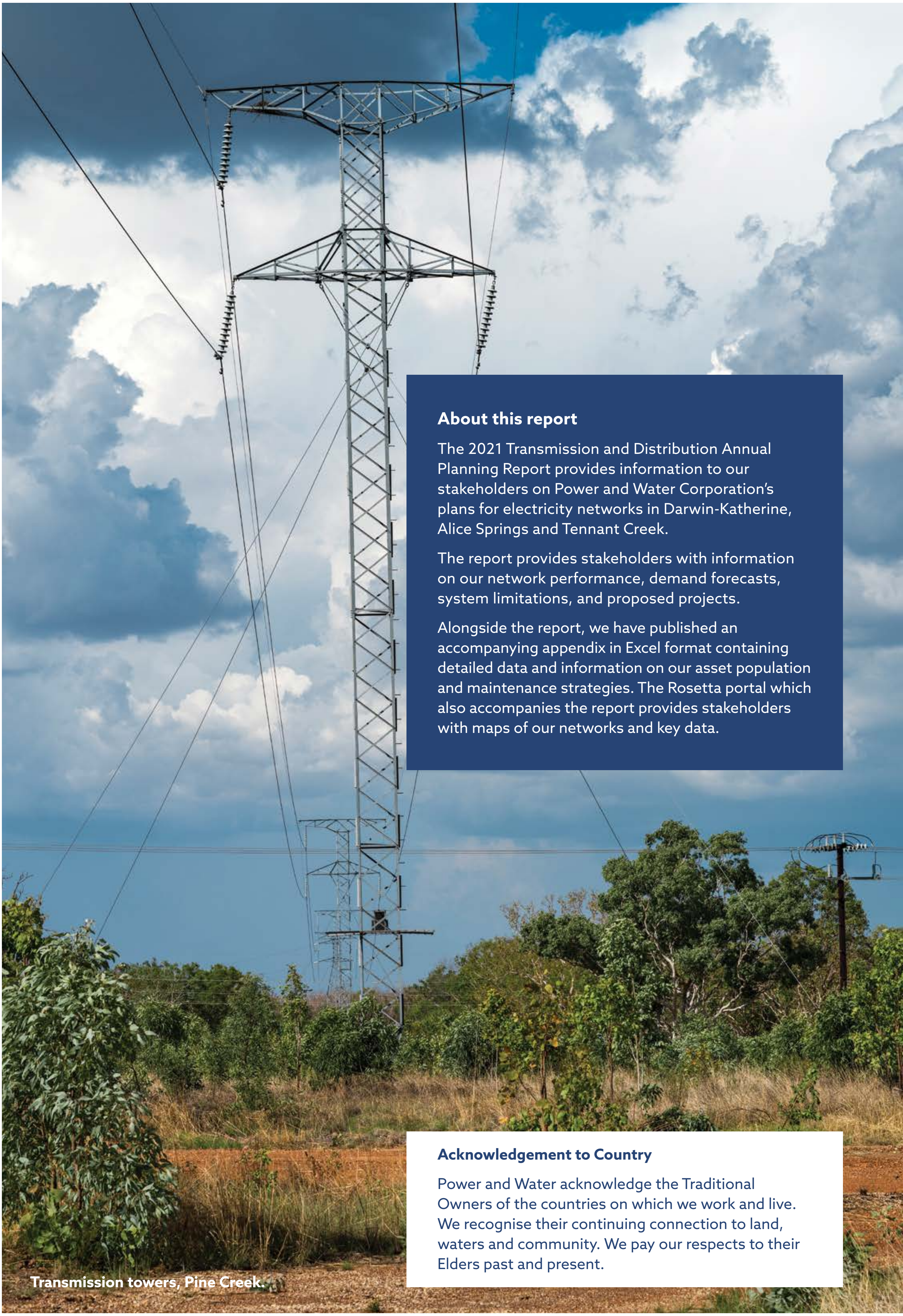
PowerWater

Transmission and Distribution Annual Planning Report

2021



About this report

The 2021 Transmission and Distribution Annual Planning Report provides information to our stakeholders on Power and Water Corporation's plans for electricity networks in Darwin-Katherine, Alice Springs and Tennant Creek.

The report provides stakeholders with information on our network performance, demand forecasts, system limitations, and proposed projects.

Alongside the report, we have published an accompanying appendix in Excel format containing detailed data and information on our asset population and maintenance strategies. The Rosetta portal which also accompanies the report provides stakeholders with maps of our networks and key data.

Acknowledgement to Country

Power and Water acknowledge the Traditional Owners of the countries on which we work and live. We recognise their continuing connection to land, waters and community. We pay our respects to their Elders past and present.

Transmission towers, Pine Creek.

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Chief Executive Officer Foreword

I am pleased to present to you the 2021 Power and Water Transmission and Distribution Annual Planning Report.

This year's report comes on the back of the release of the Northern Territory Government's Darwin-Katherine System Plan and in the midst of a renewed engagement program with our customers as we prepare for the 2024-2029 Australian Energy Regulator submission.

These key milestones along with our continued journey into the national regulatory framework have given us a richer and more meaningful report than ever before.

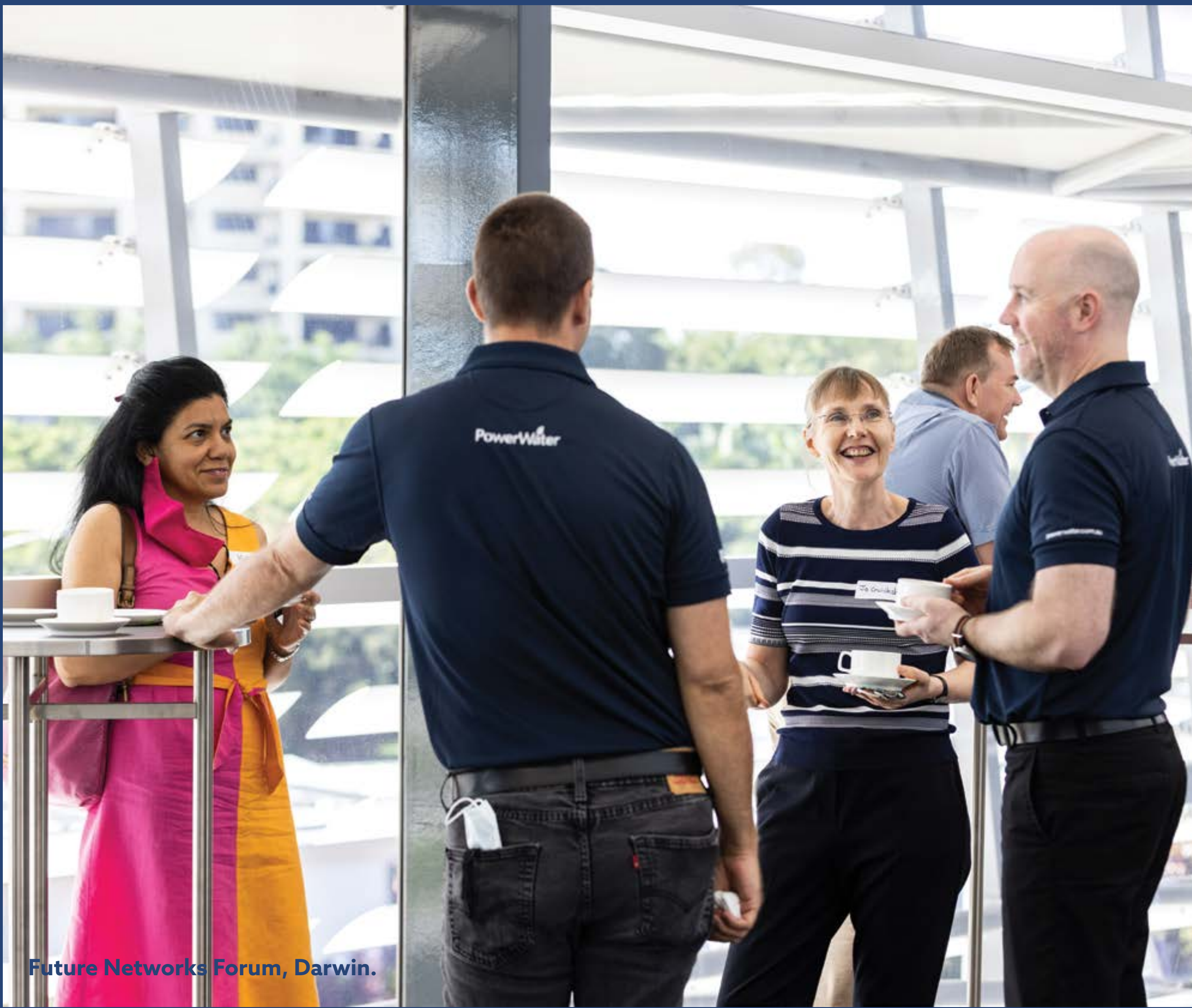
The top down guidance of the Darwin-Katherine System Plan and the bottom up feedback from our customers means a more cohesive and considered plan for how we, as the network service provider, can best meet the challenges that lie ahead. This includes supporting our customers through the energy transition that will see even greater renewable energy on the grid, coupled with more consumer-driven responses to sustainability like the rapid take-up of electric vehicles. Through the Future Networks Forum and our People Panel sessions in Darwin and Alice Springs, we have asked our customers and stakeholders about what they expect from us in a changing energy landscape. Our stakeholders have told us that we need to be thinking ahead and carefully investing in systems and infrastructure that can adapt to the changing network, while keeping a lid on our expenditure.

In this year's report we identify key focus areas to enable an efficient and agile network for the future.

Our performance over the past year is also included in this report and shows we are continuing to make ever-increasing strides to improve the customer experience and we have plans in place to continue that progress over the coming years and into the next regulatory control period from 2024.

Djuna Pollard
Chief Executive Officer

Our stakeholders have told us that we need to be thinking ahead and carefully investing in systems and infrastructure that can adapt to the changing network.



Future Networks Forum, Darwin.

People's Panel, Alice Springs.

Rooftop solar, Alice Springs.

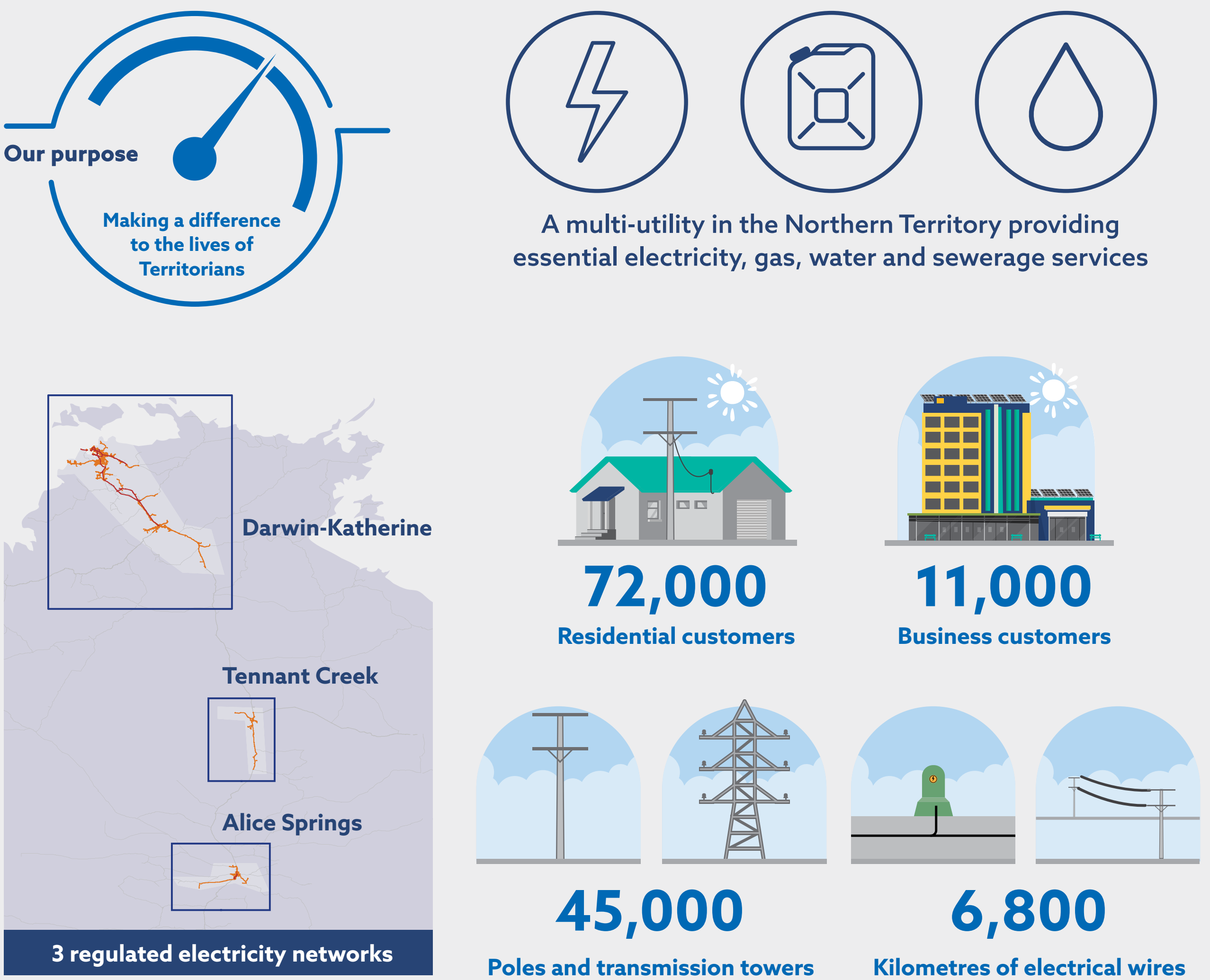
1. Summary

Over the last decade we have improved reliability, while facilitating significant uptake of small scale renewables. With rapid acceleration in solar and storage batteries expected by 2030 and with electric vehicles on the horizon, we are shifting our planning lens to the long-term. In this year's report we identify key focus areas to enable an efficient and agile network for the future. We also identify key limitations on the network over the next 10 years, and the capital expenditure works that may be required.

The summary is designed for stakeholders who are short on time, and want to get a quick understanding of our future plans.

Figure 1 provides a quick snapshot of our network and customers with more detail provided in Chapter 2.

Figure 1: Snapshot of Power and Water



1.1 Planning for the future network

In this year's TDAPR, we have identified key focus areas for our long-term planning.

Our thinking has been significantly influenced by feedback from our customers and stakeholders in recent engagement sessions. This includes the Future Networks Forum and our People Panel sessions.

Renewable energy will accelerate

Energy systems around the world are in a state of transition. Renewable technology has provided a great opportunity to reduce carbon emissions and reduce the cost of energy production.

Our customers have been at the forefront of the shift to renewables. About 10 per cent of all energy consumption came from our customers solar panels. More recently, we have seen large scale solar farms connect to our transmission network.

We are only on the cusp of an accelerated shift to renewable energy.

In October 2021, the Northern Territory Government released the Darwin-Katherine Electricity System Plan (System Plan) which provides a pathway to achieve 50 per cent renewable energy by 2030. As seen in **Figure 2**, the plan forecasts a significant injection of large scale solar, a doubling of small scale solar and significant investment in small and large storage batteries.

The System Plan will have significant implications for Power and Water's network. It includes a Renewable Energy Hub where large scale solar and battery will connect to available capacity on our transmission network. We anticipate this planned approach to generation will reduce the costs of connecting solar farms to our network and maximise the renewable energy sent out.

We will also need to carefully consider how to integrate more small scale solar into the grid. This will require innovative solutions to overcome inherent issues with exporting rooftop solar.

It is not only in Darwin where we are seeing a clear shift to renewable energy. In Alice Springs and Tennant Creek a significant proportion of customers have taken up rooftop solar. The solutions for Alice Springs and Tennant Creek will need to fit the unique attributes of these networks.

Beyond 2030 – Ageing assets and electric vehicles

Looking beyond 2030 we anticipate our networks will face further challenges. This includes the ageing of system assets, which may require significantly higher rates of replacement compared to today's low levels.

Further, we expect electric vehicles (EVs) to accelerate rapidly after 2030 as seen in **Figure 3**. The network will need to deliver significantly more energy to enable charging of EVs. This provides a great opportunity to improve the utilisation of our network if customers charge in off-peak periods.

Focus Areas

In Chapter 3 of this report, we outline three focus areas that will guide our longer-term planning of the network:

- Facilitating and unlocking renewables efficiently and securely.
- Developing strategies to maintain the health of the network as assets age.
- Incentivising EV charging when the network has spare capacity.

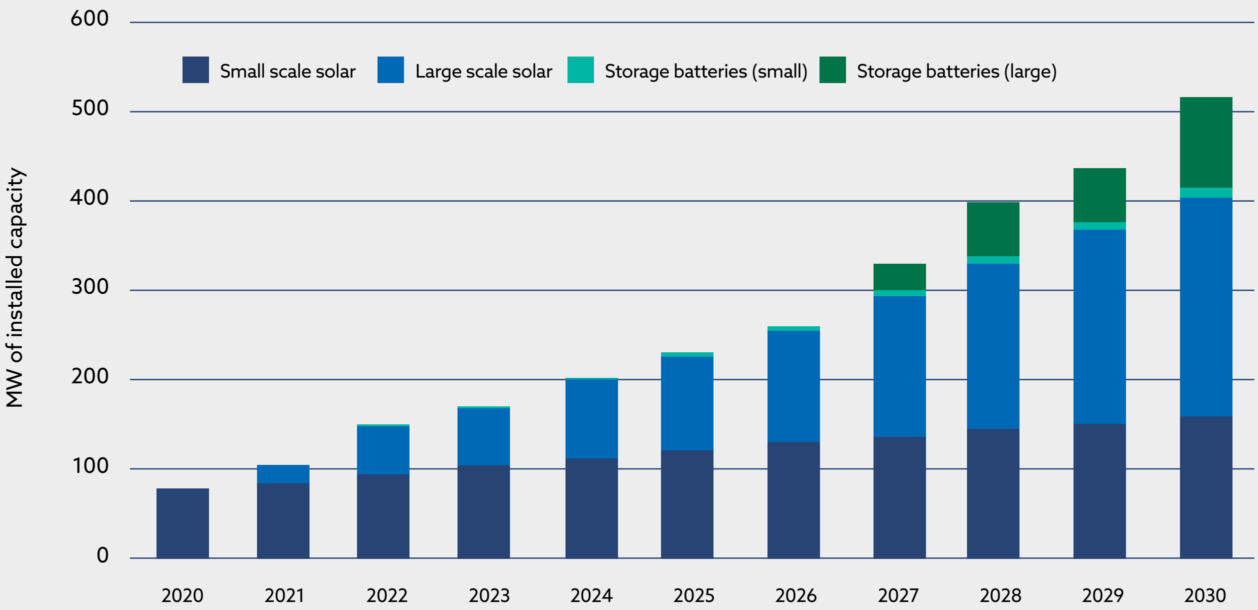
In the short term, we are building our knowledge and capabilities in these focus areas. In November 2021, we published the Future Network Readiness Plan which set out our key research initiatives.

The initiatives involve improving our understanding of the low voltage network, exploring the feasibility of community batteries and researching the impact of EVs on our network. The Demand Management Innovation Allowance provided by the Australian Energy Regulator will be used to fund the research.

We are also a partner in the Alice Springs Future Grid project. This focuses on microgrid feasibility and orchestrating renewable resources in Alice Springs.

The learnings of these initiatives will inform the development of a Future Network Strategy for the 2024-29 regulatory period that will guide prudent expenditure plans.

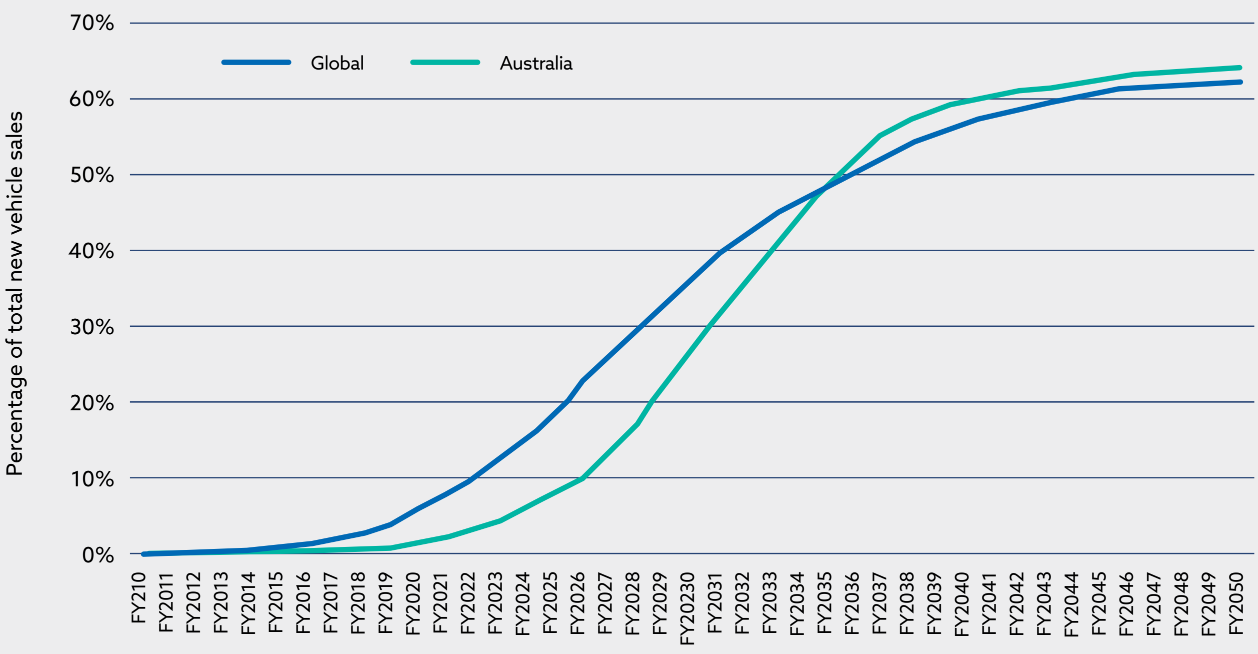
Figure 2: Forecast of renewable energy installed in Darwin-Katherine



Under the central scenario in the Darwin-Katherine Electricity System Plan, installed renewables will grow from about 80MW in 2020 to over 500MW by 2030. This includes a doubling of small scale renewables to about 160MW, about 250MW of large scale solar and 110MW of battery storage.

Source: Darwin-Katherine Electricity System Plan Input Data, Tab: Summary Table

Figure 3: Forecasts of electric vehicle sales



Electric vehicles are forecast to increase rapidly over the next decade in Australia. This means customers will be using our electricity network to charge their cars, rather than petrol and diesel.

Source: Bureau of Infrastructure, Transport and Regional Economics (BITRE), 2019, Electric Vehicle Uptake: Modelling a Global Phenomenon, Research Report 151, BITRE, Canberra ACT


Rooftop solar, Alice Springs.


Electric car charging.

Transmission towers, Darwin.

1.2 Performance in 2020-21

Power and Water has continued to provide reliable services to customers in 2020-21. On average, a customer endured 144 minutes of outages and 2.23 outage events. While weather can impact year to year performance, this continues our positive performance over the last seven years as seen in **Figures 4** and **5** below.

Reliability performance varies considerably across our customer base with outage length and frequency much higher for customers in rural areas of the network. We are striving to improve the performance for customers in worse affected areas while balancing our costs.

Power and Water is also managing to maintain voltages within reasonable levels. This is increasingly challenging as more rooftop solar is being exported back into a grid that was designed for one-way flow.

Our new design specifications for embedded generation have helped us to maintain power quality to a reasonable standard. The new standards will mean the solar inverter can absorb reactive power to reduce voltage levels together with automatically reducing solar exports when voltage limits are reached. As noted in Chapter 3, we are looking at innovative solutions that can increase renewables without compromising voltage quality.

For most of our network, we are operating within the standards of voltage quality. However, the Katherine network continues to experience voltage issues. We will be addressing this issue by installing switched reactors at the zone substation to manage the reactive power changes from increasing uptake of solar.

Chapter 4 of this document outlines our 2020-21 performance in more detail, including specific programs to improve reliability and voltage quality.

Figure 4: Average duration of interruption per customer

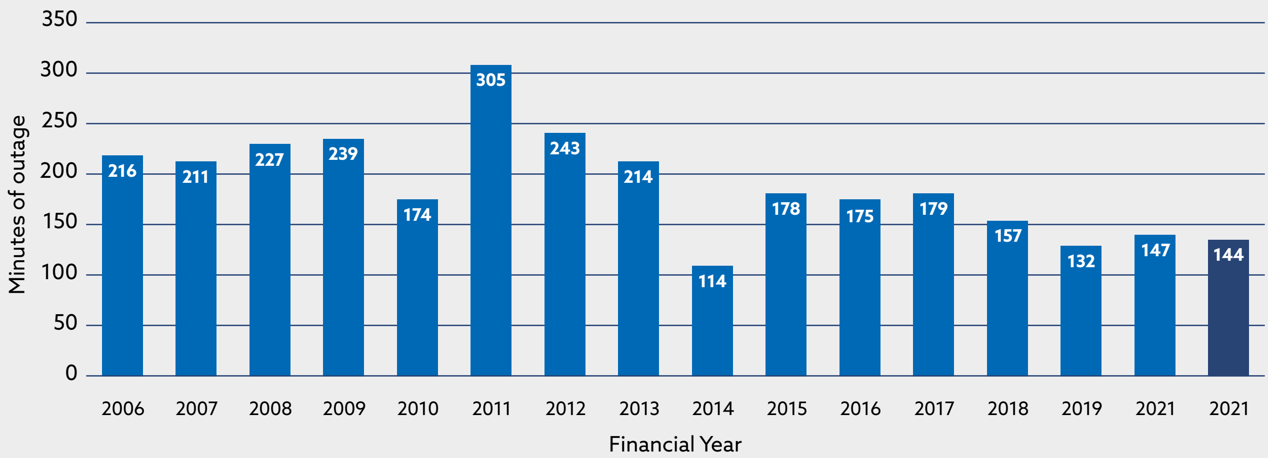
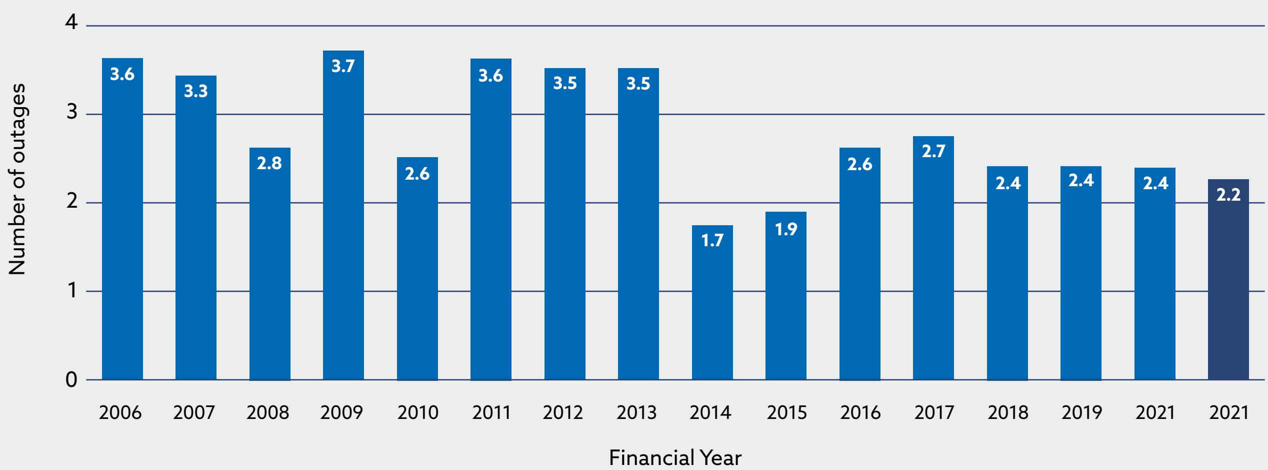


Figure 5: Number of interruptions per customer



1.3 Summary of major projects

This year we have identified capital investment over a 10 year horizon for both our transmission and distribution networks.

This will help customers and stakeholders engage more readily with our upcoming regulatory proposal for 2024-29. It also provides stakeholders with more time to put forward alternatives to network investment.

Below we identify large projects and programs over the value of $15 million. **Figure 6** shows that most of the large projects are in Darwin-Katherine, and all relate to our distribution network. We also identify other potentially large projects that may arise over the next decade but which are highly uncertain.

A detailed description of system limitations and proposed solutions are set out in Chapters 7 and 8.

Replacement capex to address asset condition

Over the next decade, the key driver of our capital expenditure will be replacing degraded or obsolete network assets.

Our current rate of replacement of assets is exceptionally low due to the relatively young age of our assets. Further, our asset management framework only targets replacement where there are material safety, reliability or environment risks.

However, over the next decade we are expecting to see an uplift in replacement volumes as the health of our network deteriorates with age.

The three major replacement projects or programs over $15 million include:

- Berrimah zone substation – Re-building the current substation due to degradation of 66kV oil circuit breakers and 11kV switchboard. The project is already underway and will be completed in 2023-24 at a cost of $30 million over the next three years.
- Darwin high voltage cables – Replacing a portion of cables in the northern suburbs of Darwin due to insulation and sheath issues from water ingress. This program has already commenced and will be ongoing till 2030 at a cost of $34 million.
- Alice Springs corroded poles – Replacing poles that are corroded and which may lead to safety issues. The program has already commenced and will continue for the next decade at a cost of $18 million.

Augmentation capex to address capacity limitations

Over the last five years, peak demand growth has been relatively flat as more customers use solar to meet energy needs. While we expect demand to increase over the next decade particularly in Darwin, capacity limitations will only arise in locations where we expect an increase in housing and industrial development.

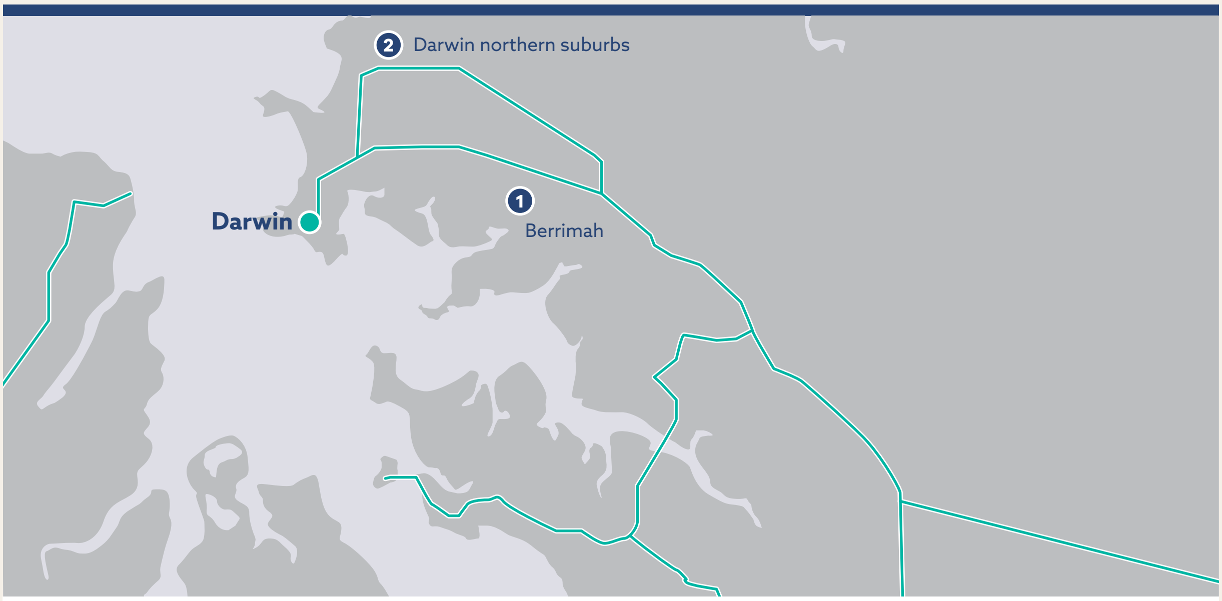
The major committed project is at Katherine. In last year's report we noted a capacity limitation related to expansion of housing at East Katherine. In this year's report we have identified the need to increase the capacity at Katherine to meet higher demand. The timing of the project is 2025 to 2026 at an estimated cost of $20 million.

There is also the prospect of four other major projects driven by large connection loads, however the timing and magnitude is uncertain. This includes:

- While not committed, we expect a significant increase in demand at Humpty Doo in Darwin. This may require a larger upgrade to the planned replacement of the zone substation and may require additional transmission infrastructure.
- A new zone substation is likely to be required to meet industrial growth in East Arm. However, there is uncertainty on the timing of connections to the area.
- A new zone substation may be required to meet demand from a new urban district in Holtze, near Palmerston. However, no firm commitments are in place at this stage.
- As noted in section 1.1, there is also the prospect of a major project to build transmission works to connect a new Renewable Energy Hub south of Darwin. We are working with the Northern Territory Government to understand our role in the implementation of the initiative.

Finally, we note that proposed national cyber security measures may require significant upgrades to our system assets, including our communications network. We will report back to our stakeholders on these uncertain projects in next year's TDAPR.

Figure 6: Major projects (over $15 million) over the next 10 years



1 Replace zone substation

Condition issues with transformers and circuit breakers

Timing 2024

2 Replace high voltage cables

Insulation issues with underground cables

Timing Ongoing beyond 2030

3 Katherine zone substation

Upgrade due to increased demand from new housing estates

Timing 2025-26

4 Replace and remediate poles

Replace poles that are corroded from salt exposure and are unsafe

Timing Ongoing beyond 2030

2. Our network

Power and Water provides electricity services to customers in the Northern Territory. Our electricity networks in Darwin-Katherine, Alice Springs and Tennant Creek are regulated by the Australian Energy Regulator. We deliver about 1700GWh of energy to about 85,000 customers in these regions. The way we operate and maintain our network is greatly influenced by our relatively small size and extreme weather conditions.

2.1 Power and Water's electricity network

Power and Water is a Northern Territory Government owned corporation that provides electricity, water, sewerage and gas to our customers.

In Australia, it is unique to provide such an array of essential services. This reflects the small population in the Northern Territory compared to other states and territories. Providing a pool of corporate and system services helps deliver services at a lower cost helping us mitigate some of our scale disadvantages.

The Power Services division of Power and Water plans, builds, operates and maintains the distribution and transmission electricity networks.

Our role in the electricity network is depicted in **Figure 7.** We transport the energy produced by large scale gas and solar generators through our transmission and distribution network to the premises of our customers. In recent times, our role has further expanded to transport the exported energy of our smaller customers who produce solar behind the meter.

Some of our electricity network services are regulated by the Australian Energy Regulator under the NT National Electricity Rules (NT NER).[1] A key reason for regulation is that customers have very limited alternatives to get electricity. Regulators protect customers by reviewing our expenditure plans to ensure they are prudent and efficient, and by regulating the amount of revenue we can collect.

The networks under Australian Energy Regulator regulation include:

- The Darwin-Katherine network supplies the city, suburbs and surrounding areas of Darwin and Palmerston, the township of Katherine and its surrounding rural areas.
- The Tennant Creek network supplies the township of Tennant Creek and surrounding rural areas from its centrally located power station.
- The Alice Springs network supplies the township and surrounding rural areas from the Ron Goodin Power Station and the Owen Springs Power Station.

The three networks are not physically connected to each other due to the distance between the regions.

We operate a transmission network in Darwin-Katherine and Alice Springs only. Our zone substations are the connection point between our transmission and distribution networks. The zone substations transform the electricity from 66kV into 22kV and 11kV voltages before they are transformed to lower voltages via our distribution substations. **Figure 8** provides a diagram of each network including location of transmission and distribution lines. The Rosetta portal accompanying this report provides an interactive map to these locations.

Chapter 7 provides more information on each of our major asset classes and their population in our regions.

[1] Power and Water also provides electricity services to customers in remote and regional areas of the Northern Territory. These parts of our network are unregulated and not subject to AER oversight.

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Figure 7: Role of Power and Water in the regulated Northern Territory electricity market

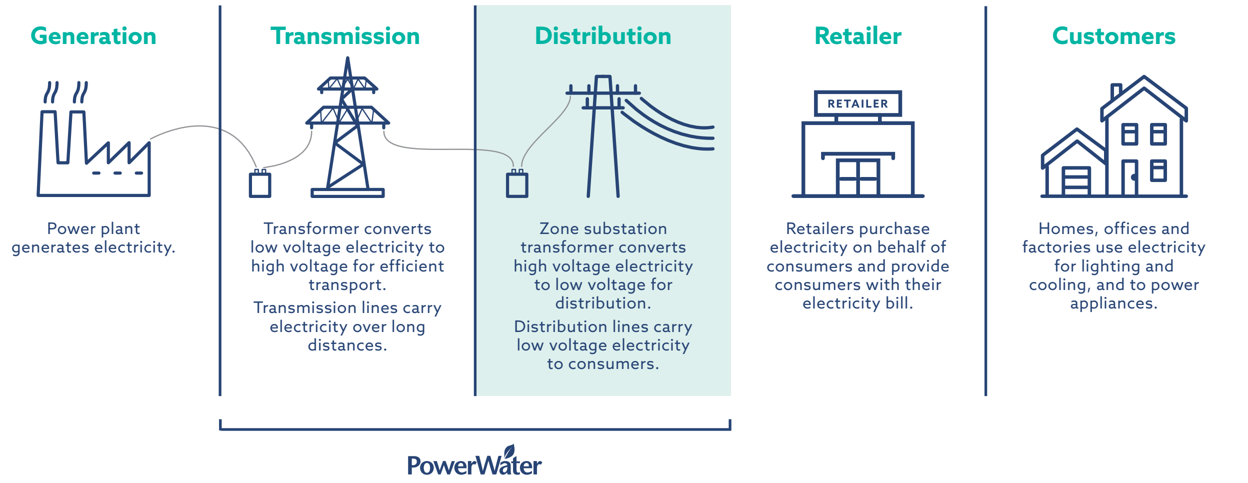
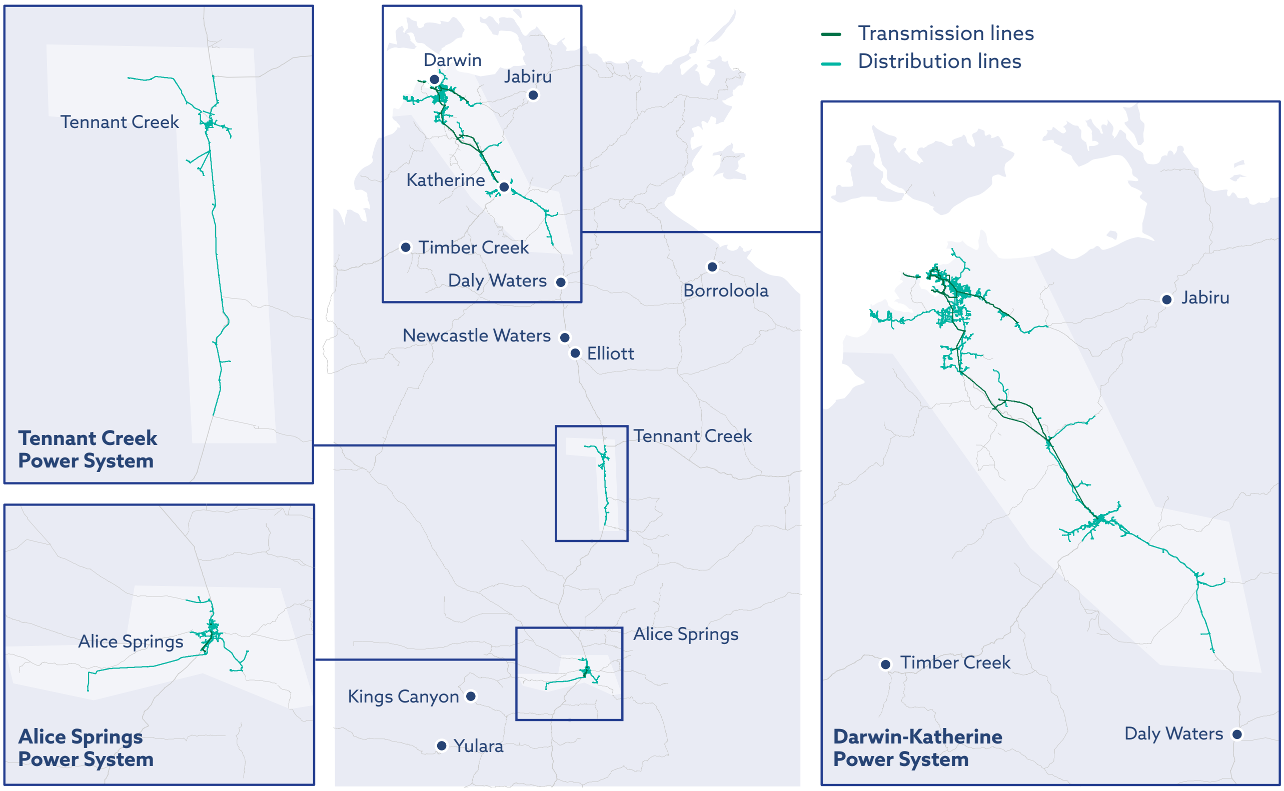


Figure 8: Regulated areas of Power and Water's electricity network



2.2 Our customers and community

Power and Water's primary purpose is to make a difference to the lives of Territorians.

Our electricity network provides essential energy to about 85,000 customers across our three regulated networks. We deliver almost 1700GWh of electricity to power homes and businesses.

Over 85 per cent of our customers are residential, requiring electricity for essential appliances such as fridges, air conditioning and cooking.

Many of our residential customers have rooftop solar. As active participants in the energy market, our customers use the network to transport their solar back into the grid.

Businesses represent only 15 per cent of our customers, but account for 70 per cent of energy consumption. This shows why our network is an essential backbone of the Northern Territory economy.

Listening to our customers

In recent times, we have been making a genuine effort to involve customers in our decisions and plans.

Our upcoming regulatory proposal for the 2024-29 period is an opportune time for customers to test and provide feedback on our expenditure plans. We have launched an extensive engagement program to ensure the voice of customers is reflected in our decision making.

Over the last three months we have been talking to all our stakeholders on their preferences and expectations. This includes:

- Customer Forums – In September and October, our leadership team met with customers in Darwin and Alice Springs to hear their experiences of our network, and what we should be prioritising.
- People Panel – In an exciting new concept, Power and Water has selected a representative group of customers to provide feedback on our strategic direction and expenditure plans. In November of this year, our leadership team spent two weekends with our People's Panels in Darwin and Alice Springs discussing and road testing our strategic direction.
- Future Networks Forum – Our major customers and broader stakeholders participated in a question and answer panel session on Power and Water's role in a changing energy system.
- Youth Round Table – We held a round table with our younger customers to understand what they want from Power and Water for future generations.

Framing our conversations

Engagement requires Power and Water to understand the world from the eyes of the customer, and for customers to step into our world. This has been the lens we have tried to bring to framing our discussions with stakeholders.

Figure 9 is the 'Customer Lifecycle' – our attempt to understand what customers expect and want from us across their journey as a customer. This includes when they connect, when the power is on, when power is interrupted and when power is disconnected.

With our People Panel, we were able to delve into key strategic issues facing Power and Water. This included our role in facilitating renewables, how best to compare ourselves to other peer networks, how to manage an ageing asset base, and how to best integrate electric vehicles.

What we have heard so far

We are reflecting on what our customers have told us, and will bring this back to the table in terms of our plans. The key messages we have heard from customers so far are:

- Get more renewables on the grid, but weigh up the costs and benefits of solutions.
- We need to test how we perform against other networks using sensible benchmarks, but make adjustments for the unique circumstances of operating in the Northern Territory.
- We need to avoid price shocks and major reliability incidents by managing our assets and budgets in the long term.
- We need to plan ahead for electric vehicles.

Power and Water Corporation's primary purpose is to make a difference to the lives of Territorians.

Figure 9: Customer lifecycle framework

Customer journey	Customers want	Customers expect us to
Connecting	• Fast connection • Easy connection • Timing that suits them	• Be ready to connect • Have capacity in the network • Coordinate big and small connections efficiently
Power on	• Reliable energy • Fair pricing • Rewards to solar customers for exporting power to network	• Manage solar exports • Manage maintenance • Manage vegetation • Maintain and read meters • Coordinate with retailers
Power interrupted	• Restore power quickly • Communicate timing of outage • Minimum invasion of their property or goods in repairs	• Undertake emergency repairs • Coordinate customer calls • Follow up on reported outages
Disconnected	• Timely disconnection if moving out • Prompt and clear billing • Prompt reconnection if error or when payment made	• Determine why disconnected • Reconnect where required • Schedule disconnection • Disconnect on time if requested • Support customers to avoid disconnection

2.3 Our operating environment

Our network has many unique characteristics that impact on the way we operate the business.

Small scale

We have the smallest electricity network compared to other networks in the National Electricity Market on measures such as customers, energy volumes and peak demand. This can be seen in **Figure 11** which shows that Power and Water has significantly less customers than other networks.

Our lack of scale leads to a cost disadvantage when compared to other networks in the National Electricity Market. **Figure 12** shows that Power and Water needs to construct more metres of line per customer. We also have to meet the same regulatory obligations as larger networks, but have to spread the costs over less customers.

Transmission network

We are the only network in Australia that has complete carriage of transmission and distribution functions. Our transmission network in Darwin-Katherine and Alice Springs is extensive with about 400 kilometres of transmission line, 3000 towers and four sub-transmission substations. Being a transmission operator also means we need to ensure that large scale generators can connect safely to our network.

Extreme weather

Power and Water also operates in extreme environments particularly in Darwin which has high humidity in the wet season and is prone to destructive cyclones and tropical storms. We also have extreme heat compared to other places in Australia as seen in **Figure 10**.

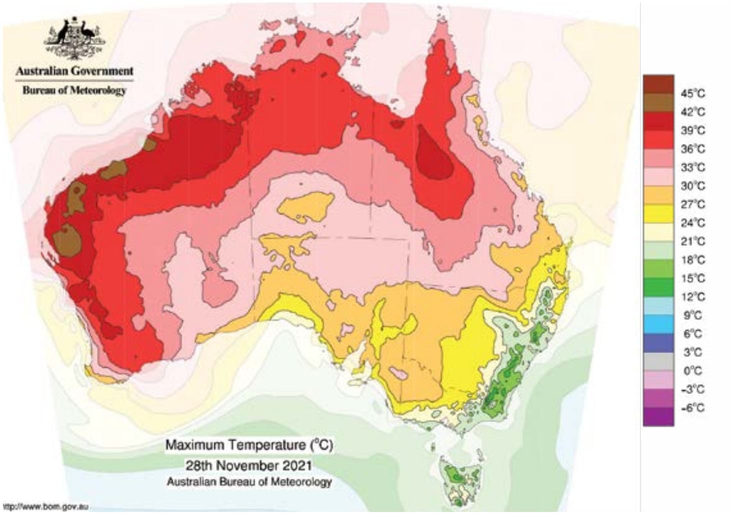
These conditions tend to increase our emergency management costs compared to other networks and can lead to more wear and tear of our network assets. Weather also impacts on labour productivity in humid weather, with our field crew's productivity impacted by the extreme conditions.

Unique regulations

Like all other networks, we have licence and reporting obligations and must comply with environmental regulations. We also have unique obligations that impact our costs:

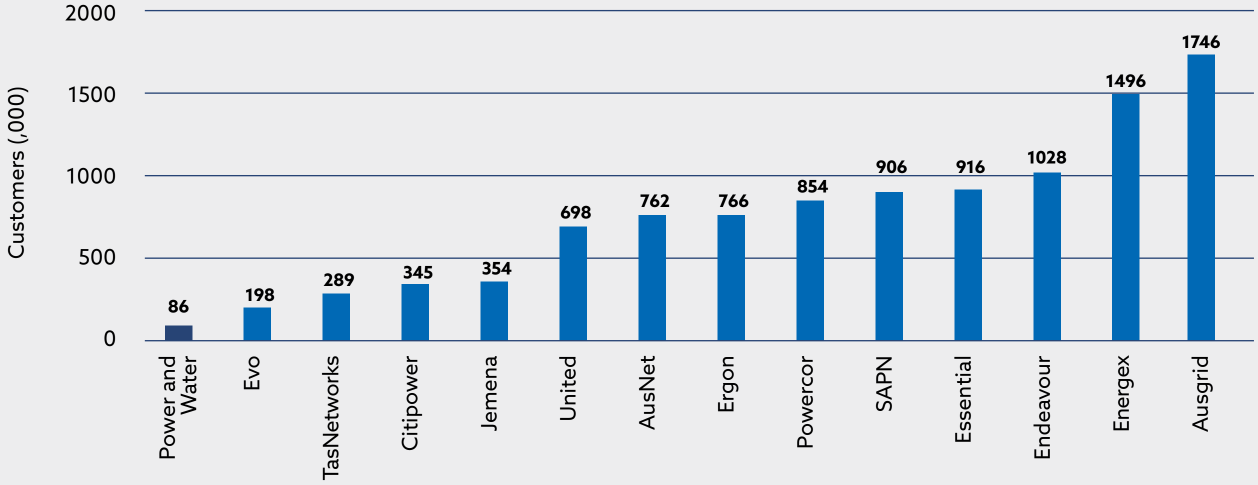
- Travel to and from sensitive environmental areas requires mitigation practices which increases time and cost to undertake network activities.
- The Northern Territory has many sites of cultural significance and all programs of work need to assess and mitigate against adverse cultural heritage impacts leading to additional costs.

Figure 10: Extreme heat areas in Australia



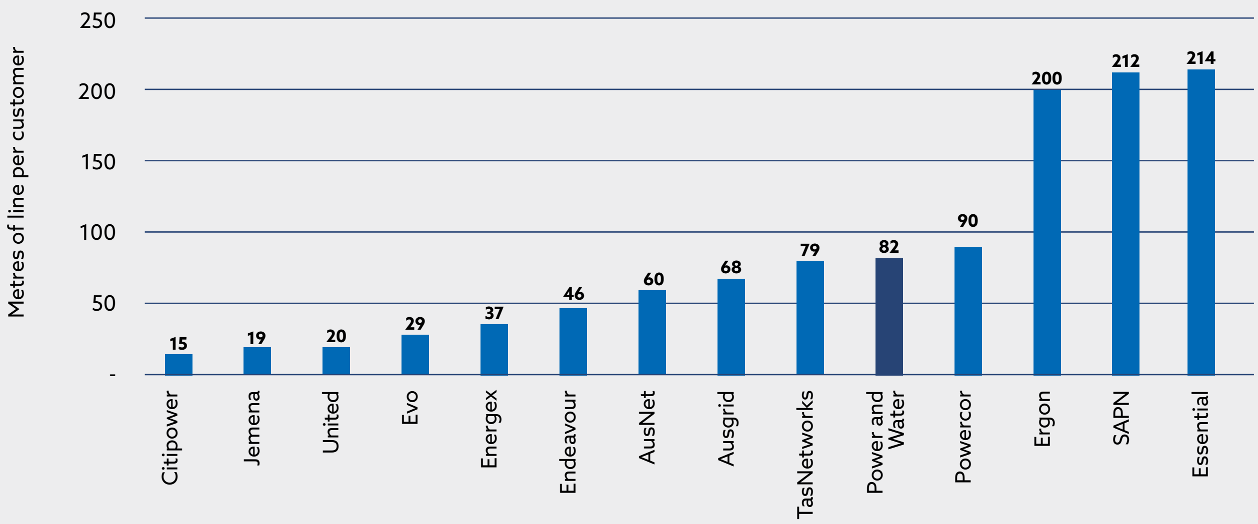
The Northern Territory has extreme heat conditions which means our customers use more energy in the day for air conditioning. It also means that our workforce need to work in extreme heat conditions, impacting productivity.

Figure 11: Customer numbers by distribution network (,000)



Power and Water has the lowest number of customers in the National Electricity Market. The second smallest network is Evo Energy which has 2.5 times as many customers. Ausgrid the largest network has 20 times the number of customers as Power and Water.

Figure 12: Total metres of line per customer by distribution network



Power and Water has to build significantly more network (cables and conductors) to provide electricity to each of its customers. This means that while we service a capital city (Darwin) our network is more similar to a rural network, which has diseconomies of scale from having to build longer networks.

Figure 13: Future Networks Forum

Panel at Future Networks Forum, Darwin.

At our Future Networks Forum in November 2021, our stakeholders asked questions of our Panel members who had a variety of expertise in planning for the future. We discussed how Power and Water needs to adapt to changes in the electricity sector.

3. Future network - focus areas

The last five years has seen rapid change in the electricity system in the Northern Territory, as customers install solar in their houses and businesses. The pace of change will accelerate with the Darwin-Katherine Electricity System Plan which sets out a pathway to reach 50 per cent renewables by 2030. We have been working with experts and our stakeholders on what role Power and Water will play in facilitating a renewable energy system by 2030. We have also been strategically considering other challenges facing the network by 2030 including the ageing of network assets and increased peak demand from electric vehicles.

Our network has reached a pivotal turning point where it is necessary to refresh and re-shift our traditional approach to planning the network.

As discussed in section 1.1, we expect a significant acceleration in solar and storage batteries by 2030 and beyond. Further, we have other challenges beyond 2030 including how to manage an ageing network and integrating the expected demand for energy from electric vehicles.

This requires a shift to long term strategic planning so that we can ensure we keep the network reliable and secure, and prices affordable.

It is critical that our customers and stakeholders have a voice in how we plan for the future. In November 2021, we held a Future Networks Forum (see **Figure 13**) where major customers and other stakeholders discussed Power and Water's role in a rapidly changing energy landscape. We also engaged with our People Panel in Darwin and Alice Springs on the future of the electricity network.

The key message from our stakeholders is that Power and Water needs to adapt to new drivers. However, we should sensibly balance costs and benefits, and make sure the network is reliable.

Following on from these discussions, Power and Water has been trying to synthesise the feedback to identify key focus areas. These are:

1. Facilitating and unlocking renewables efficiently and securely.
2. Developing strategies to maintain the health of the network as our assets age.
3. Developing incentives for customers to charge EVs when there is spare network capacity.

We look forward to testing our thinking with stakeholders in upcoming engagement sessions in 2022 and responding to the feedback.

It is critical that our customers and stakeholders have a voice in how we plan for the future.

3.1 Facilitating and unlocking renewables

Renewable solar has the potential to improve electricity affordability for customers.

From a network perspective, rooftop solar has helped curb investment in new poles and wires. In the Northern Territory, maximum demand occurs in the daytime as customers need air conditioning in the extreme summer conditions. This coincides with maximum production of solar. As a result, peak demand growth has fallen on our network by one per cent per annum since 2015 as more customers use their own power rather than the network.

This can be seen in **Figure 14**, which shows that solar self consumption has reduced peak demand on our network. However, as discussed in section 3.3, solar is reaching its limits with peak demand now occurring in the evening.

Analysis produced by the Northern Territory Government also suggests that renewables are cheaper than thermal generation. The Darwin-Katherine Electricity System Plan found that generation costs could be $30 million less each year compared to re-investing in thermal generation.
The savings reflect three key advantages of solar in the Northern Territory:

- Price – The price of solar and batteries has substantially reduced over the last decade.
- Sunlight – The Northern Territory has an abundance of sunlight, so the relative production of energy per solar panel is high compared to other places.
- Timing – About half of today's existing thermal generators in Darwin-Katherine are reaching the end of their life by 2030, meaning this is the optimal time to shift to renewables.

In this context, it is vital that Power and Water's network can transport available renewable generation.

So far, we have adopted innovative strategies to ensure we can export most of our customer's solar. But the acceleration of renewables is likely to limit how much we can transport through our networks. The challenges we face are set below.

Connection of large solar in Darwin-Katherine

A key issue for Power and Water is that solar farms are connecting at different locations to existing thermal plants in Darwin-Katherine. Our transmission network is set up to transport energy from Channel Island and Weddell.

Many solar farms are connecting south of this transmission corridor onto the Darwin-Katherine transmission line. This line was designed to send power south to Katherine but is now being used to transport significantly more generation north to Darwin. The transmission line is operating close to its constraints and would require significant augmentation to transport any more renewables.

Voltage control

Our network was designed for one way flow from large generators to customers' premises. Rooftop solar requires the network to reverse the direction of power. This can cause voltage excursions outside the normal range, which negatively impacts the quality of supply.

To address this issue, Power and Water reduced the voltage at our zone substations in Darwin to manage the high voltage on the distribution feeders caused by rooftop solar. However, this solution is reaching its limits as more rooftop solar connects to our network.

Recently, we amended our connection specifications for new solar installations to have inverters with Volt-Var and Volt-Watt capability. This utilises the var absorption capability of the inverters to assist in keeping the high voltages within limits. Following the var absorption capability of the inverters being exhausted, the volt-watt function activates and the inverter 'ramps down' solar exports.

The new specifications for inverters assist in keeping voltage on the system within limits and overall allows more renewable energy to be exported to the grid without static export limits. We would expect that as more small scale solar connects onto the grid, more of this generation will be curtailed at critical times of the day using the Volt-Watt capability as different sections of network reach voltage limitations.

Growing rooftop solar also heightens the current issues with high voltage on the transmission network.

Minimum demand

Currently, the energy system needs a threshold level of thermal generation to keep the power system in balance. On mild but sunny days, we are approaching a scenario where there is not enough demand for thermal generators to operate.

This is termed the 'minimum demand' challenge and is facing most networks in Australia. The key issue is that solar production is maximised on sunny days but demand for electricity is low due to the limited need for air conditioning on days of the year where the weather is less humid and hot.

Figure 15 shows that minimum demand has fallen significantly since 2017 as a result of increased rooftop solar installations.

To address this problem we would need to either limit renewable production on these days, or rely on alternative technology such as grid-scale batteries or synchronous condensers.

Figure 14: Comparing underlying maximum demand in Darwin-Katherine to maximum demand delivered by the network

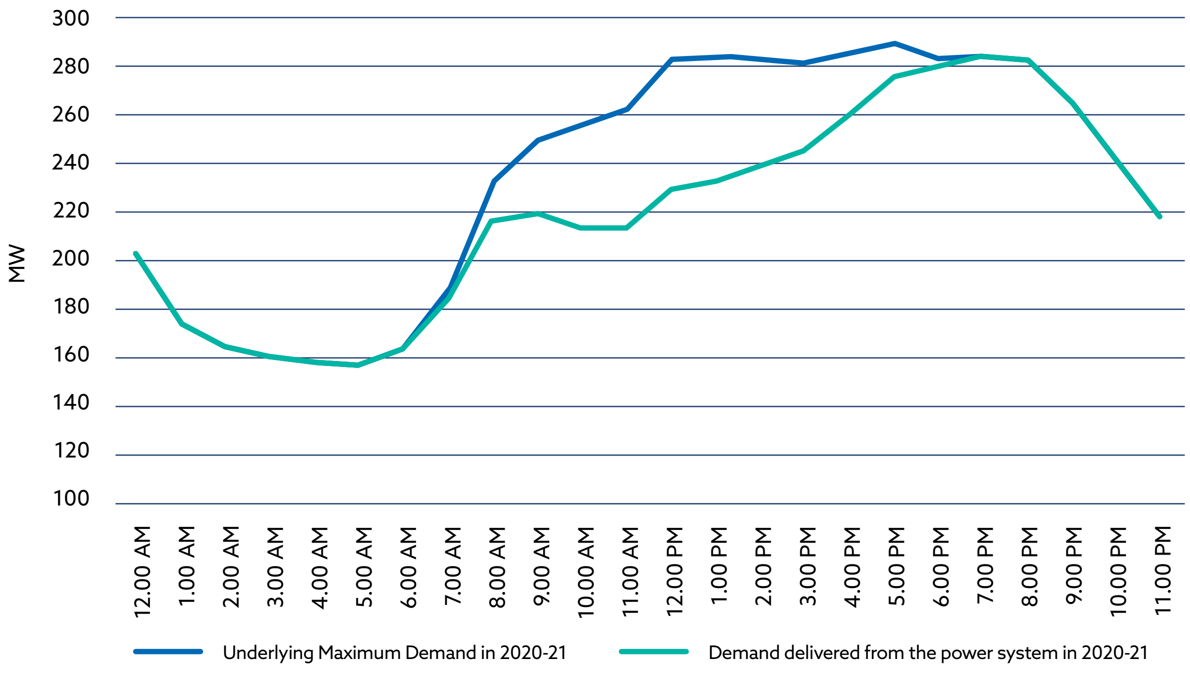
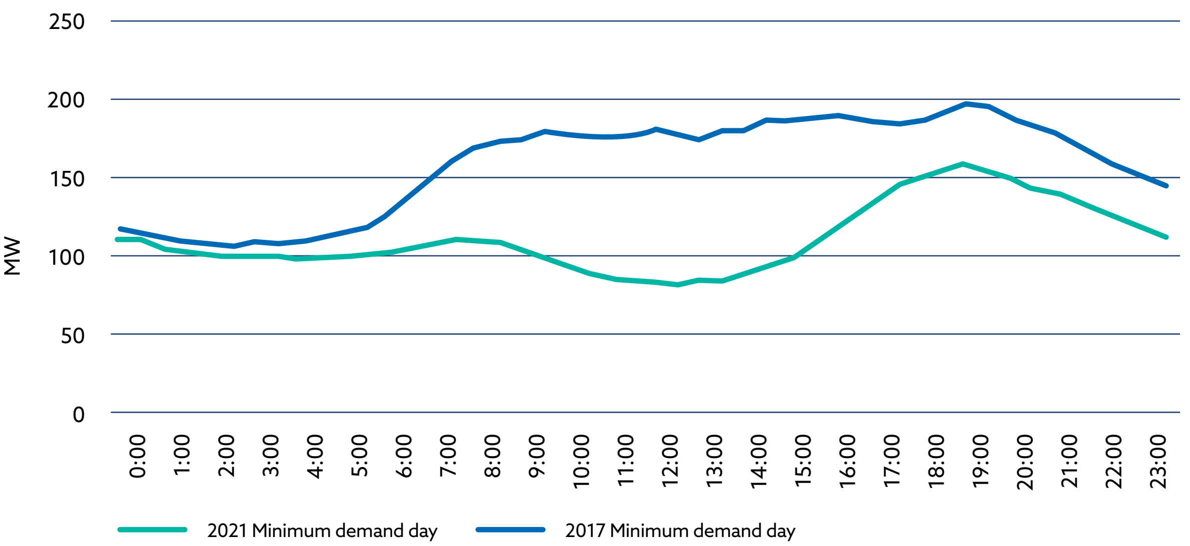


Figure 15: Comparison of minimum demand in Darwin-Katherine in 2021 to 2017



Focus areas to efficiently unlock renewables

In the coming months, we will be developing a Future Network Strategy that will guide our proposed expenditure for the 2024-29 regulatory proposal. In developing our expenditure plan, we will focus on two key areas.

1. Design efficient transmission network

Our first strategy is to design the transmission network to connect new large-scale renewables at lowest cost. This has the benefit of reducing our long term transmission costs and improving affordability for all customers.

The key to lower costs is for generators to locate close to existing transmission infrastructure with spare capacity.

For this reason, we strongly support the concept of a Renewable Energy Hub identified in the Darwin-Katherine Electricity System Plan. The first renewable hub would see about 200MW of solar and 100MW of batteries co-locate south of Darwin.

The hub would be connected via transmission infrastructure to our existing 132kV transmission line between Channel Island and Hudson Creek. With the retirement of ageing generators, there will be sufficient capacity on this line to dispatch solar production. We consider that generators would be incentivised to locate in the hub due to lower connection costs and maximum dispatch of generation.

While this would involve a significant upfront cost, we consider it is the most efficient means of utilising our existing transmission infrastructure. We will work with the NT Government on how the Renewable Energy Hub will be implemented.

Beyond 2030, we expect even more large scale renewables to connect, and deliver higher levels of energy to support growing demand.

This means the transmission landscape is likely to become complex in the future and may require expansion. We consider that transmission costs are likely to be minimised through more Renewable Energy Hubs that allow for centralised, rather than piecemeal expansion of the transmission network.

2. Cost effectively unlock small scale solar

In its current design, the network will not be able to securely export all of the expected generation from rooftop solar due to voltage and minimum demand challenges.

This adversely impacts on customers installing new solar who cannot maximise their investment. But it is also a lost opportunity to reduce generation costs for all customers, as solar is less expensive than thermal generation as indicated in the Darwin-Katherine Electricity System Plan.

Our focus will be finding solutions that unlock renewables at low cost, where we can demonstrate a net economic benefit to customers. Key strategies we will investigate include:

- Increasing solar exports by getting a better understanding of the voltage and thermal limits of the low voltage network. This would allow us to develop dynamic operating envelopes in different areas of the network.
- Storing solar energy in home and community batteries and discharging the energy in the peak evening periods.
- Demand management initiatives that shift energy consumption to the middle of the day rather than the evening peak. This includes expected high demand from electric vehicles ("EVs").

Figure 16 provides an illustration of how these strategies would come together from a street level perspective.

Figure 16: Strategies to unlock small scale renewables reliably and efficiently

1. Maximise solar output by better understanding the limits of the network at the street level in real time.
2. Use home and community batteries to capture solar in the day and discharge at night when the sun is down.
3. Use appliances (including EVs) from solar and home batteries during the day rather than night to manage demand.

3.2 Sustainable replacement

Replacement rates are well below sustainable levels for most asset classes on the network. On average, we expect most network assets to have a lifespan of about 50 to 60 years. Over the long term, a sustainable level of replacement would be about 1.5 to 2 per cent per annum.

Figure 17 compares the average annual replacement rates over the last seven years for each major asset class with the sustainable rate over the long term. This shows that annual replacement rates are well below the sustainable level for all asset classes except transformers.

There are many reasons why Power and Water has been able to maintain reliability despite low levels of replacement including:

- Our network assets are relatively young with only four per cent of the total asset value older than 50 years.
- We proactively manage the health of our assets through inspections, condition based monitoring and refurbishment.
- We only undertake planned replacement when there are material safety, reliability or other risks from the degraded condition of the asset.

Smoothing prices in long term

Price spikes occur when there is a substantial increase in costs over a short period. A sudden increase in prices can have adverse impacts on customers, particularly financially vulnerable households and businesses in the Northern Territory.

In 2008, we experienced a situation where our costs increased significantly due to the condition of assets on our network. Several failures at Casuarina zone substation resulted in widespread, sustained power disruption to Darwin's northern suburbs. Further investigation found that most major substations were in poor condition, often beyond repair and with a high risk of failure. This resulted in a substantial increase in replacement costs of zone substations.

Our experience in 2008 shows that we need to maintain the condition of our assets before they cause disruption to service. Our early analysis suggests that by 2030 we will need to significantly increase replacement to maintain the reliability of the network. This is because a large cohort of our assets were built after Cyclone Tracy in 1974, and will be over 55 years of age by 2030.

Figure 18 shows that a significant proportion of our assets will be older than 50 over the next 20 years. At current rates of replacement, 20 per cent of assets will be older than 50 years by 2030. By 2040, this would increase to 40 per cent. Such an aged network would lead to significant risk of asset failure and the potential for cascading failures.

Figure 19 provides an indicative analysis of replacement volumes to 2040. This is based on age modelling using a similar approach to the Australian Energy Regulator's calibrated replacement expenditure model. The findings are confronting – for most assets we expect an exponential increase in replacement.

Strategies discussed with our People Panel

In our November 2021 sessions with our Darwin and Alice Springs People Panel, we discussed strategies to minimise the risk of future price shocks.

Customers were generally supportive of our current strategy not to spend a dollar more before required, but also wanted us to focus on addressing reliability risks before they happened.

In particular, our customers wanted us to present more detailed analysis on asset ages and potential impact on prices from replacement in the future.

Key strategies the People Panel wanted us to think about were:

- Extending the lives of assets while minimising risk.
- How we can use new technology such as solar and batteries to avoid re-investing in network infrastructure when assets fail.
- Smoothing mechanisms to mitigate against price shocks. This included the idea of customers paying a small premium to save funds for replacement in the future.

Figure 17: Annual replacement of major assets – current vs sustainable

	Poles	Conductors	Cables	Services	Transformers	Switchgear
Population	45000	5300km	1600km	56000	4900	7000
Annual Replacement	100	5km	5km	150	95	90
Sustainable Replacement	650	75km	25km	1400	100	150

Figure 18: Proportion of asset base over the age of 50 at current rates of replacement

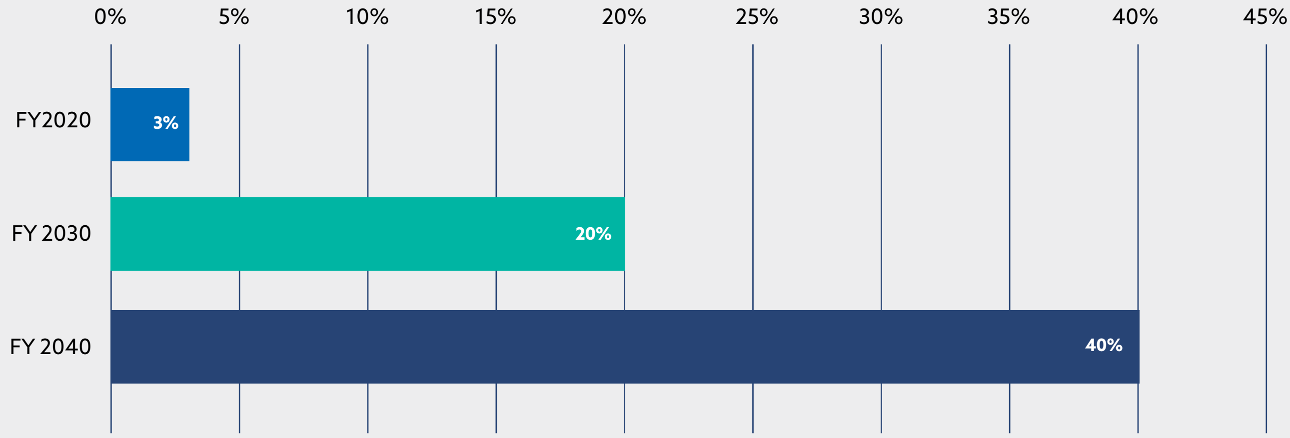
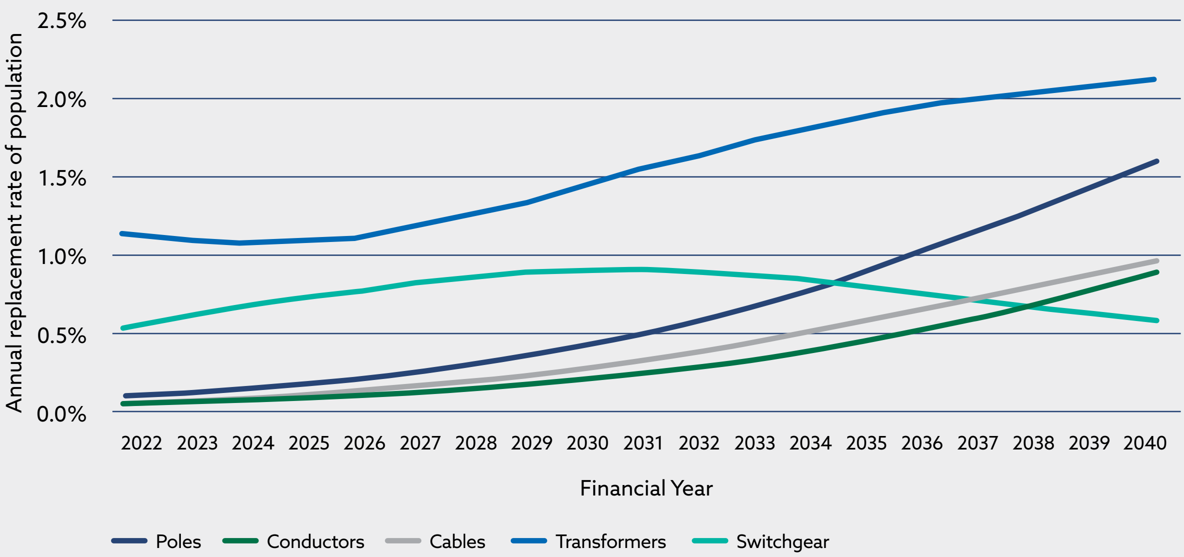


Figure 19: Forecast replacement volumes to 2040 due to ageing of asset base



EV charging.

3.3 Managing demand from electric vehicles (EVs)

A key driver of new network investment is growth in peak demand. As discussed in section 2.1, peak demand has fallen over the last five years due to customers using solar in the middle of the day.

Peak demand now occurs in the evening when solar customers can no longer access generation from their panels. This also means that solar has reached its threshold in how much it can help reduce network peak demand.

This is reflected in the latest outlook from the Northern Territory Utilities Commission, which shows that peak demand is likely to rise again over the next decade. This is discussed further in Chapter 6.

The network currently has spare capacity to meet a moderate increase in demand across the network from population increase and economic activity. However new connections in localised areas such as industry precincts and housing developments will drive new infrastructure over the next decade.

EV impacts post 2030

Looking beyond 2030 we see that electric vehicles will drive a significant increase in energy consumption. On average, each car could add about 30 to 40 per cent to a typical household's consumption. While this will increase the electricity bill, customers will save significantly more on fuel.

EVs also present a vital opportunity to improve affordability of network electricity.

The utilisation of the network will improve if EV owners charge when there is spare network capacity. Higher utilisation means the network can help improve affordability for each unit of energy delivered. In contrast, if customers charge their EVs in congested periods, we will need to build new infrastructure to meet higher peak demand.

Figure 20 shows three typical charging profiles from current residential EV users in NSW, based on data from Australian Energy Market Operator. It shows that many customers charge in the evening after coming home from work (termed a 'convenience charge'). There are some customers who charge in the daytime, generally at work. There are also customers who predominantly charge overnight.

Figure 21 provides early analysis of how EV charging may impact the network on a maximum demand day in 2040. Modelling undertaken by Dynamic Analysis, shows that daily energy consumption in Darwin-Katherine may increase by about 25 per cent by 2040, under a scenario where 50 per cent of vehicles are electric. The analysis assumes that some charging is undertaken by the customer using their own solar panels.

If customers charge mostly in the evening, then peak demand may increase by close to 50 per cent compared to today. This would require significant infrastructure, and lead to lower utilisation of the network.

If most customers charge in the day, network peak demand would be about 27 per cent higher than today, despite customers using their own solar. While this is far better than evening charging, it still would require significant investment.

Overnight charging delivers the best outcome with only a two per cent increase in peak demand growth in the network. This is because the network has significant capacity overnight. Under this scenario, minimal infrastructure would be required but utilisation would improve, translating to improved affordability.

While this analysis suggests night-time charging is optimal in Darwin-Katherine, there are other factors that will need to be examined in detail. This includes that generation costs are most likely to be lower in the day than evening. Further, daytime charging may also help resolve minimum demand challenges as EV charging would push demand higher.

As noted in the next section, it is vital that this type of analysis be undertaken at a spatial level. We recognise that there may be pockets of the network such as the city or highways that will have intense charging needs.

Figure 20: EV charging patterns in NSW

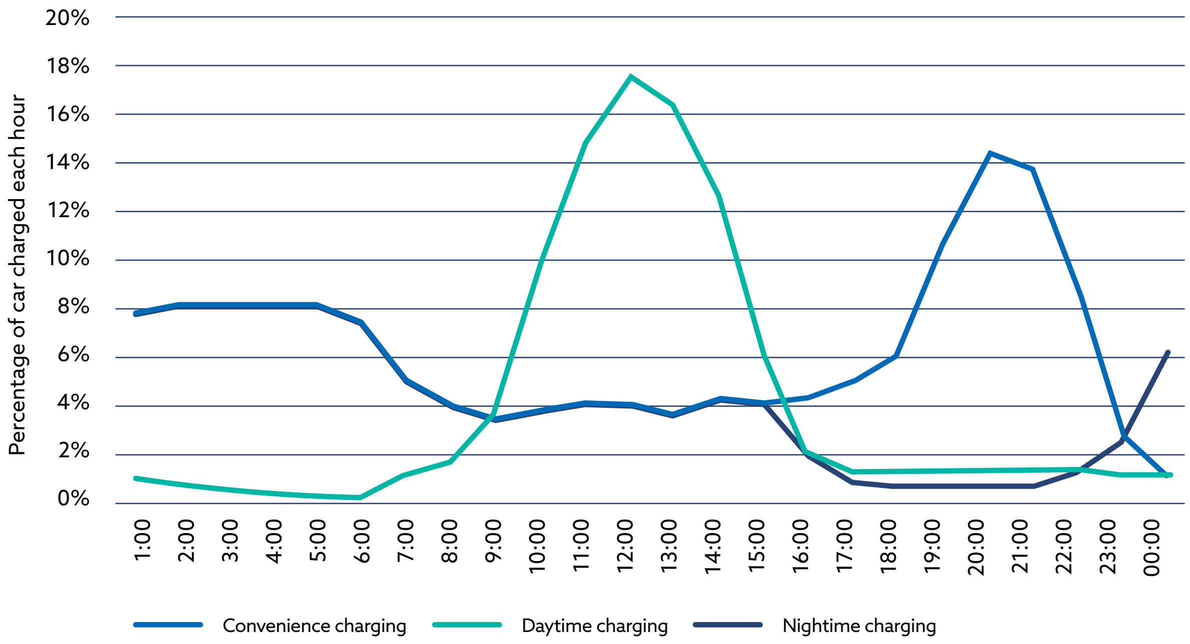
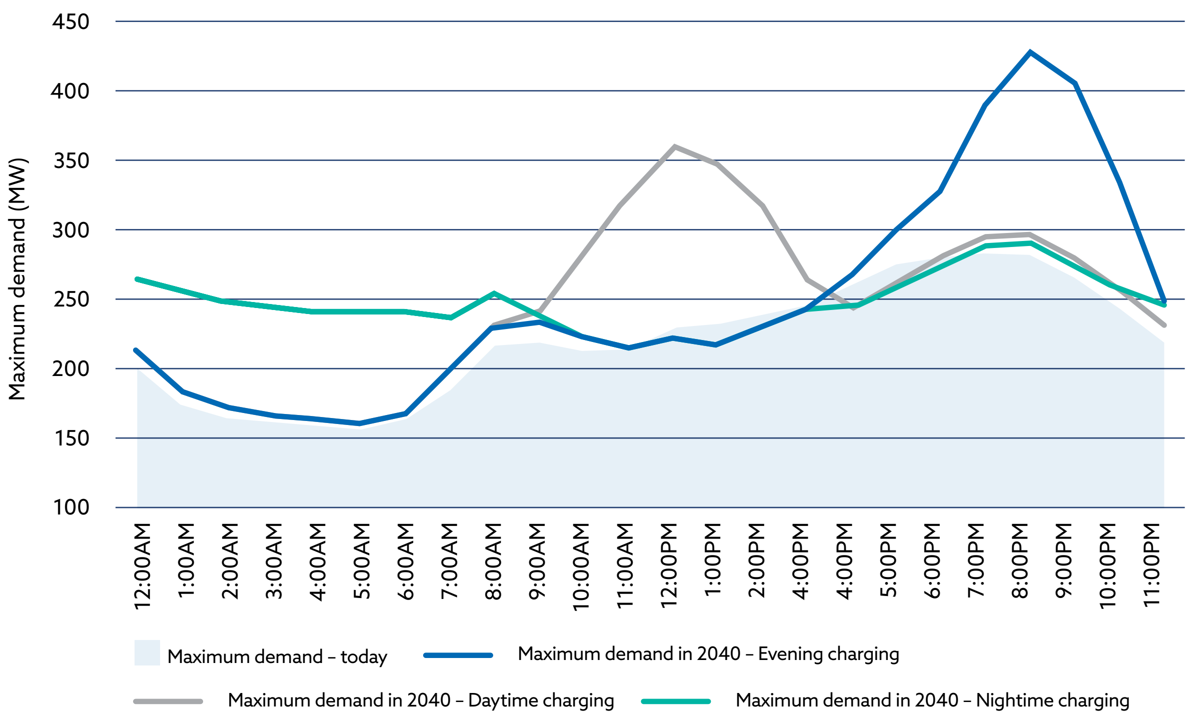


Figure 21: Impact on maximum demand in Darwin-Katherine by 2040 under EV charging patterns



3.4 Future Network Readiness Plan and other pilot

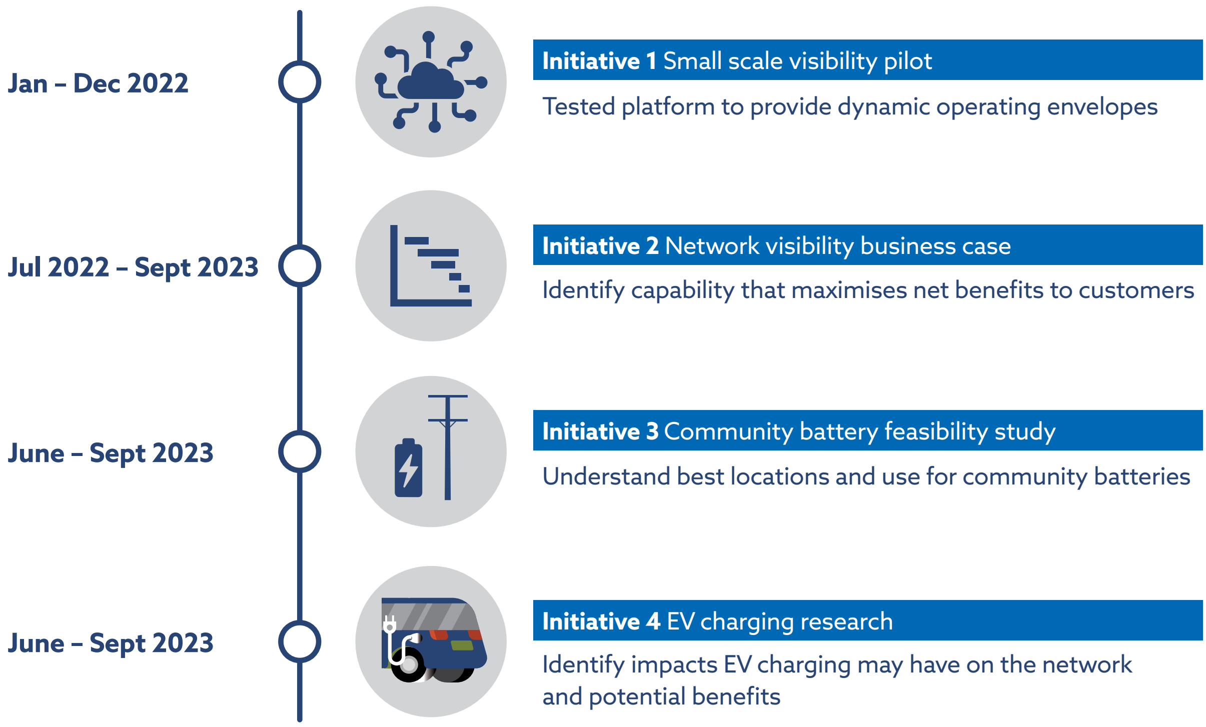
Power and Water released a Future Networks Readiness Plan in November 2021. The document outlines four key initiatives that help us address a current knowledge or capability gap including:

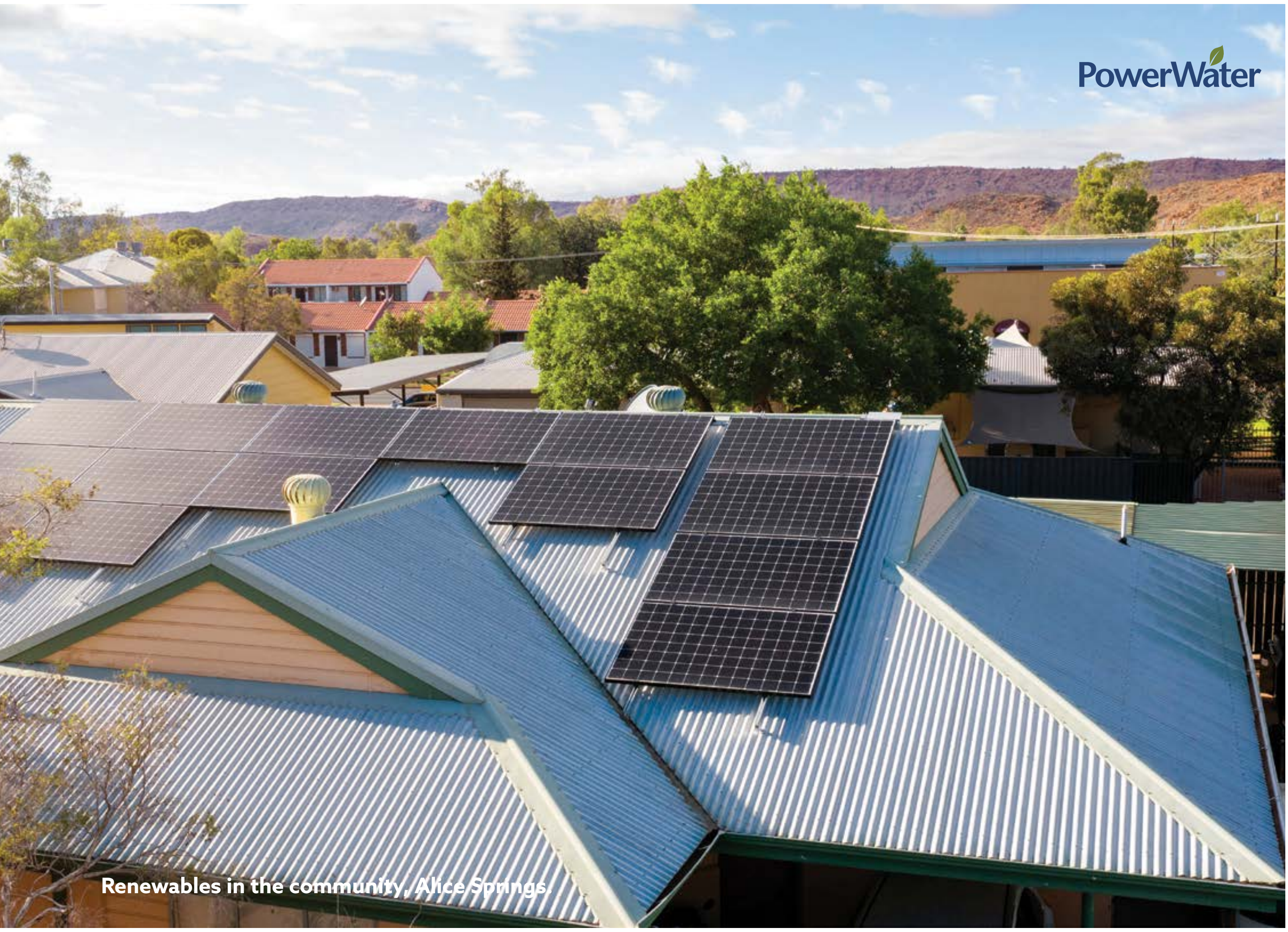
- Small scale visibility pilot – Power and Water has limited ability to monitor the two-way flow of energy at the street level. And even if we could see what is happening, we cannot respond in real time. This project looks to understand what solutions are available to provide real time visibility, and provide tools to unlock renewables based on a better understanding of network limits.
- Network visibility options – Building on the pilot above, this initiative would help us develop a business case assessment of the data issues and capability solutions.
- Community battery feasibility study – Community batteries are located in a local neighbourhood, utilising the excess capacity of solar and discharging that energy during peak times. The project will assess where batteries are best placed in the network and their optimal use.
- EV charging research – This will determine localised network issues from EV charging at home and in the workplace.

The initiatives will use funding available under the Demand Management Innovation Allowance (DMIA). **Figure 22** shows the expected timing of the projects and the outcomes.

In addition to these initiatives, we are also involved in the Alice Springs Future Grid project. This is a two-year initiative to enhance renewable energy capability developed in the Alice Springs network and share it to other grids and jurisdictions. This focuses on modelling and future grid capability, microgrid feasibility and trialing and orchestration of renewable resources.

Figure 22: Future Network Readiness Plan initiatives





Renewables in the community, Alice Springs.

Power and Water engineers.

4. Network performance in 2020-21

Over the last decade, Power and Water has significantly improved reliability performance. In the 2020-21 period, we maintained our reliability performance across our network but fell short of our targets for long feeders in rural areas. We also maintained a good quality of supply despite an increase in solar on the network. The exception is in Katherine where we plan to put forward a program to correct voltage issues.

The TDAPR provides an opportunity for our stakeholders to assess the performance of our network on an annual basis. The typical measures of network performance include reliability and quality of supply.

4.1 Reliability performance

Our customers expect us to minimise the frequency and duration of power interruptions. In this section, we report our reliability performance against key metrics set out in our regulatory requirements.

The Northern Territory Electricity Industry Performance Code (EIP Code) is the applicable regulatory instrument for setting our reliability metrics and targets. The EIP Code provides a framework for setting reliability measures and standards for Power and Water's regulated network.

Below we describe how Power and Water performed in 2020-21 against the key metrics in the EIP Code including reliability performance by feeder category and worst performing feeders.

Power and Water is not subject to the AER's Service Target Performance Incentive Scheme (STPIS) for the 2019-24 period. For this reason, we do not provide a submission to the AER on our performance against the scheme, nor do we provide forecasts of our performance.

However, we still report our reliability performance in our response to the Australian Energy Regulator's Regulatory Information Notice (RIN). We note that reporting definitions are slightly different in the EIP and RIN, and therefore our performance data differs in each of our reports.

Feeder performance in 2020-21

The EIP Code requires Power and Water to propose reliability targets for 2019-24 for approval by the Utilities Commission.

This includes targets for System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) by feeder category on the distribution network.[2] The SAIDI is average minutes off supply per customer, and SAIFI is the average number of interruptions experienced per customer.

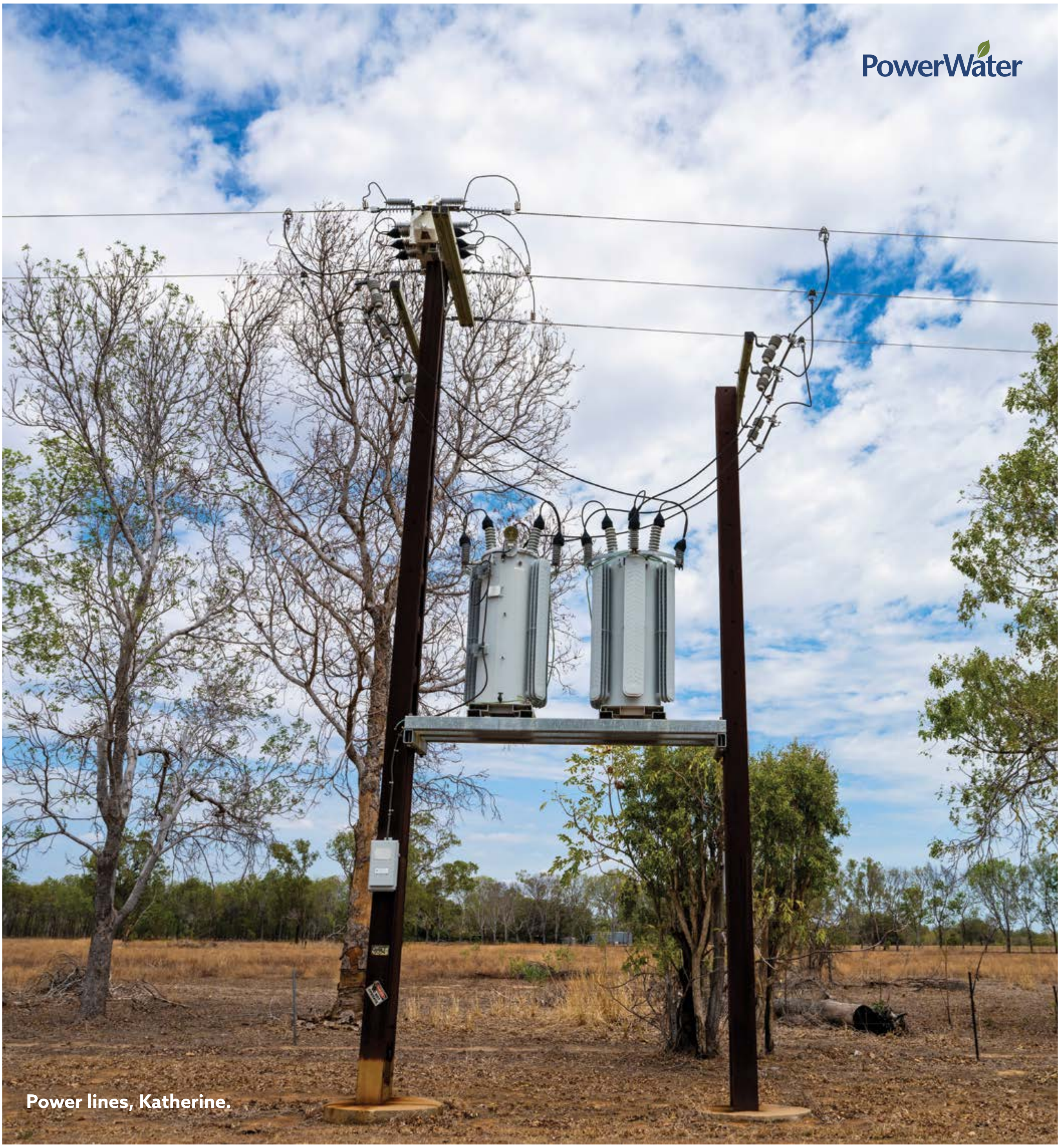
Our annual performance can markedly differ from year to year due to weather and other unpredictable activity.

Table 1 reports our 2020-21 SAIDI and SAIFI performance by feeder category against the targets approved by the Commission under the EIP Code.

For the CBD, our reliability performance for duration of outages marginally fell short of the target, but in terms of frequency we met the target.

For urban and rural short feeders, we performed better than the reliability targets for outage duration and frequency. In contrast, we did not meet our target for frequency and duration on rural long feeders, similar to last year.

[2] In calculating the performance metrics, the Code requires that all transmission networks are classified as distribution networks and their performance is reported as for the distribution network. For clarity, any reference to the distribution system also includes the transmission system in the remainder of this section.



Power lines, Katherine.

Table 1: 2020-21 Reliability performance compared to approved target in EIP Code

Feeder category	Adjusted SAIDI[1]			Adjusted SAIFI[1]		
	Performance target	Actual performance	Performance	Performance target	Actual performance	Performance
CBD	4	4.005	Target not met	0.1	0.081	Target met
Urban	140	117.727	Target met	2	1.469	Target met
Rural short	190	149.201	Target met	3	2.450	Target met
Rural long	1500	1701.106	Target not met	19	29.097	Target not met
Whole of network	175.8	136.509	Target met	2.6	2.100	Not applicable[2]

1The recorded data is 'adjusted' to remove excluded events consistent with the reporting requirements in the EIP Code.

2 The EIP does not specify 'whole of network' targets. We derive a 'whole of network' target based on our feeder category targets.

Worst performing feeders in 2020-21

The EIP Code also requires us to measure and report on the five worst performing feeders in the CBD, urban, and short and long rural categories. This recognises that some of our customers receive worse reliability than others and we should improve performance provided it is cost-effective.

Table 2 sets out our five worst performing feeders by category for 2020-21. We outline the dominant causes of interruptions and its impact on SAIDI for the feeder. We also identify if the same feeder was identified as worst performing in 2019-20.

Customers connected to our rural feeders experience significantly worse reliability than customers connected to our CBD and urban feeders. This is due to limited interconnection to transfer load from an adjacent feeder and that the length of the route means it takes longer to find the cause of the issue.

Improving reliability performance

Our reliability improvement program focuses on areas of the network where customers consistently receive poor service, and where there are cost-effective ways to materially improve performance.

Based on our performance in 2020-21, we will not undertake specific reliability works in the CBD. Our performance has generally met the targets in previous years. Further, our planned replacement program over the next 10 years should contribute to improving CBD performance. In particular, we are planning to replace distribution substations to improve fault level capacity as outlined in section 8.3 of this report.

For urban feeders, we plan to install reclosers to improve the reliability of the McMillans feeder. This is to mitigate the issue of repeated interruptions from bats in this area. We will also provide isolation points on the feeder to restore power more promptly to other customers on the feeder. We have no other planned works.

We plan to undertake reliability improvement works on the following short rural feeders:

- In Herbert, Virginia and Howard Springs, we will install reclosers to automatically restore power caused by transient events.
- In Howard Springs, we will install a high voltage feeder tie and switch to reconfigure the network to minimise customers impacted by an outage. We will also undertake targeted vegetation management on the trees that are most adversely impacting performance.
- For McMinns and Darwin River, we will undertake a targeted vegetation management program to minimise disruption caused by trees close to the power line.

For long rural feeders, we will undertake the following programs:

- Dundee – We will install a remotely controlled switch to enable rapid restoration of supply after a reliability event. We will also install protection equipment to mitigate damage caused by animals.
- Mataranka – We will install reclosers in five locations to improve restoration times after an outage. We will also install protection equipment in areas of the feeder known to be impacted by animals.
- Ali Curung – We will install reclosers in two locations, together with installing animal guards, and animal protection on transposition poles.

Our reliability improvement program focuses on areas of the network where customers consistently receive poor service.

[3] We have only three rural long feeders on our regulated network. For this reason, these will always be reported as worst performing feeders.

PowerWater

Table 2: Worse performing feeders by category

Category	Feeder Name	SAIDI	Cause and impact on reported minutes	Same as previous year
CBD	11MS04 PEEL	3.85	Equipment failure due to heavy storm	No
CBD	11FB SEARCY	0.09	Failed electricity meter for a single customer	No
CBD	11DA17 DA-ML	0.06	Two assets failures	Yes
URBAN	11RG02 GOLF	24.33	Equipment failure adding 24 minutes of SAIDI	No
URBAN	11BE04 MCMILLANS	15.43	Unusually high bat activity in August adding 13.6 minutes of SAIDI	No
URBAN	11WN24 PARAP	14.36	2 lightning strikes adding 14.2 minutes of SAIDI	No
URBAN	11WN22 LUDMILLA	11.50	Equipment failure (GBS) adding 11.2 minutes of SAIDI	No
URBAN	22KA22 KATHERINE	7.64	Trees blown into mains events adding 4.2 minutes of SAIDI and for other events no cause found	Yes
RURAL SHORT	22SY11 HERBERT	14.64	Trees blown into mains and equipment failure (failed GBS) adding 10.873 minutes of SAIDI	Yes
RURAL SHORT	22SY03 VIRGINIA	13.68	Lightning and weather related outages adding 13.18 minutes of SAIDI	Yes
RURAL SHORT	22SY02 MCMINNS	13.57	Trees blown into mains and equipment failure (cable fault) adding 12.4 minutes of SAIDI	Yes
RURAL SHORT	22PA202 HOWARD SPRINGS	10.74	Trees blowing/falling into mains and animals adding 9.68 minutes of SAIDI	Yes
RURAL SHORT	22SY15 DARWIN RIVER	8.95	Trees blown into mains, lightning and animals adding 8.24 minutes of SAIDI	No
RURAL LONG	22SY04 DUNDEE	1465.52	Animals adding 607 minutes of SAIDI, Equipment failures added 336.4 minutes of SAIDI, weather related adding 287 minutes of SAIDI, no cause found adding 231 minutes of SAIDI	Yes
RURAL LONG	22KA10 MATARANKA 1	130.40	No cause found adding 65.5 minutes of SAIDI, weather related adding 38.2 minutes of SAIDI, equipment failure adding 16.6 minutes of SAIDI	Yes
RURAL LONG	22TC01 ALI CURUNG	76.75	No cause found adding 74.6 minutes of SAIDI	Yes

4.2 Quality of supply performance

Quality of supply relates to voltage disturbances that can impact a customer's energy supply and appliances.

Currently, Power and Water's Network Technical Code and Network Planning Criteria is the applicable standard that sets out measures and standards for quality of supply delivered to our customers.

For steady state voltage, we must apply the Australian Standards for our low voltage network.[4]

We monitor power quality issues by analysing customer complaints and actively monitoring voltage levels at our zone substations. We have permanently installed monitoring equipment in all zone substations and use portable equipment to undertake cyclic monitoring of distribution substations.

We investigate cost-effective options to resolve identified quality of supply issues. Options include distribution transformer tap adjustments, upgrading or installing additional distribution transformers, segmenting the local low voltage network between transformers, upgrading the capacity of conductors, and phase balancing.

Low voltage quality audits

We conduct regular audits of low voltage quality, using a random sample of customers. In 2021, we undertook an assessment of power quality using the data obtained from smart meters.

We note that this year's assessment includes a significantly higher sample size for each region and for the first time we have included Tennant Creek. Compared to last year, the sample size was approximately 6.5 times higher in Darwin, 3.6 times higher in Katherine and 2.1 times higher in Alice Springs. This provides a more accurate understanding of emerging voltage quality issues on the network.

Table 3 identifies the percentage of time that voltage was above or below the limits prescribed in our regulatory obligations. The key findings for this year are:

- Darwin and Tennant Creek are not showing any issues with voltage quality based on the sample size.
- Katherine is significantly above the limits for a significant proportion of the time.

We note that the low voltage quality audits are only one aspect of understanding the extent of issues with the quality of power supply. Customer complaints provide another means of identifying issues with power quality.

Customer complaints in 2020-21

In 2020-21 we received 39 complaints about quality of supply from customers compared to 29 complaints in 2019-20. **Figure 23** compares the number of complaints by category over the last three years.

We investigated each complaint of our customer to understand the underlying issue. In 2020-21, we found that the majority of causes related to an internal problem at the customer's premises, and only a portion of issues related to faulty network equipment. **Figure 24** compares the underlying cause.

Table 3: Voltage performance by region

Voltage zone	Darwin	Katherine	Alice Springs	Tennant Creek
Below limits (<216V)	0.00%	0.01%	0.02%	0.00%
Above limits (>253V)	0.00%	8.71%	0.00%	0.00%

[4] The relevant standards are AS60038 and AS61000.3.100. The range of LV supply is specified in AS61000.3.100 Section 5 and is re-produced in the accompanying appendices.

Figure 23: Quality of supply complaints

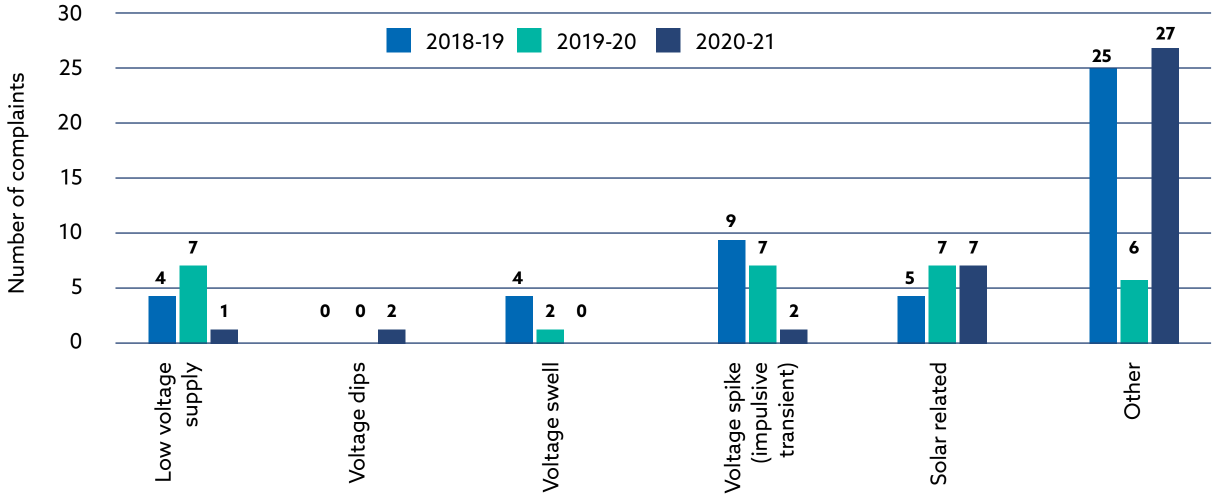
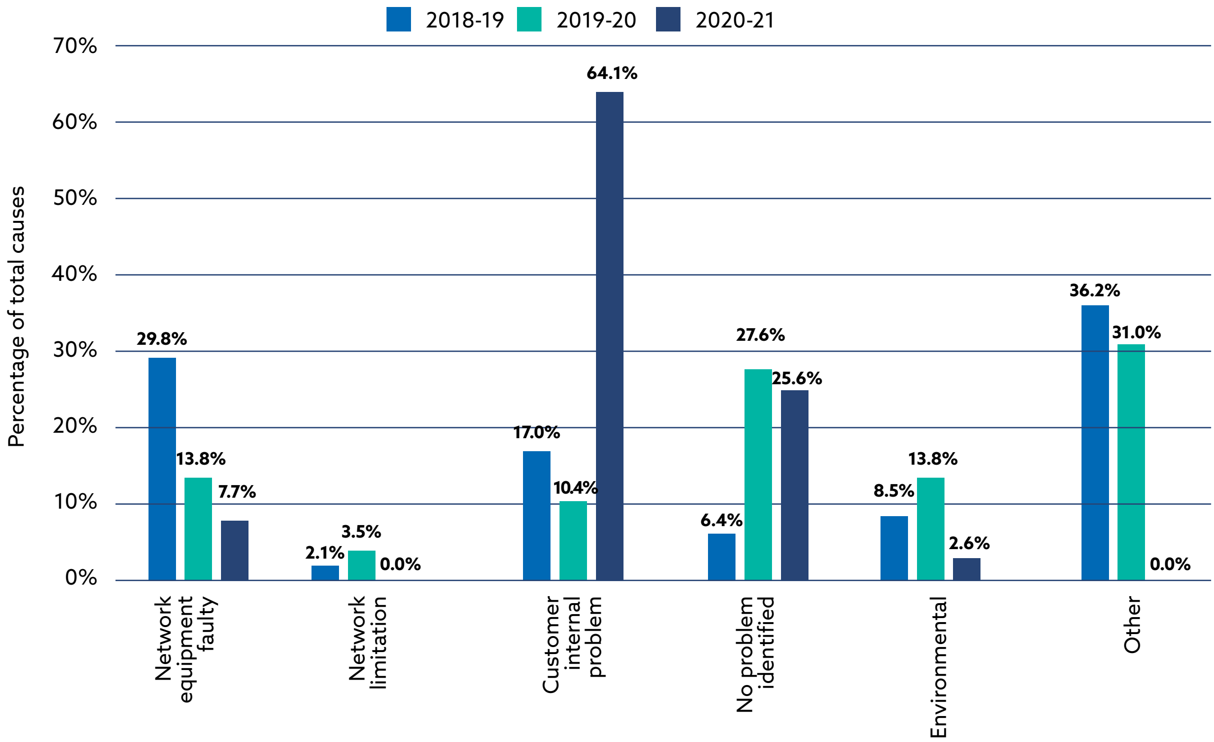


Figure 24: Quality of supply causes




Power lines, Katherine.

Improving quality of supply

Power and Water has a quality of supply program for the 2019-24 period that aims to resolve low voltage issues over time. The program includes:

• Address voltage issues at Katherine

In Katherine, we plan to install switched inductive compensation to lower voltage at the bus in the zone substation, which will have the impact of absorbing reactive power. We expect the development stage of this project to be completed by the end of 2021.

• New specifications for embedded generation

In October 2020, we introduced new technical specifications for connection of Embedded Generation (EG) systems including solar and batteries.

The specifications include mandatory Power Quality Response modes for all new EG systems. This means the inverters must respond with 'Volt-Var' and 'Volt-Watt' to mitigate voltage increases relating to small scale solar.

Since the introduction of the standard last year, there have been 1135 PV applications approved and installed in accordance with the new technical specifications.

We also received seven large embedded generators applications seeking to connect two megawatts or more solar to the distribution network. We are unable to report on the average time-frame to connect as no connection is complete at this stage. We note that three are in the detailed response phase and four are in the preliminary phase.

• Voltage management studies

We are currently undertaking studies on the optimal voltage management strategies for the Darwin-Katherine network. This will help us understand the voltage issues that are likely to arise on the distribution and transmission networks, particularly in the context of increasing renewables on the system.

The study should also help us estimate the likely level of services we will need to meet our expected obligations under the new ESS framework that the Northern Territory Government will be introducing.

• Targeted augmentation

Power and Water also undertakes targeted reconfiguration of the low voltage network in areas that are most impacted. This is likely to be older suburbs where there has been significant new housing development with solar.

4.3 ICT Update

Our Information and Communications Technology (ICT) strategy is directed at supporting key improvements to our business including:

- Driving efficiency to support our Operating Model initiatives – We have identified key investments to upgrade and implement new ICT systems to improve the efficiency of our services.
- Improving the way we communicate with customers – We have identified changes to our customer relationship management system and outage management system that improve our ability to respond to customers' enquiries and to communicate outage times.
- Improving our asset management and network planning capabilities – We have recognised that investing in analytics and data can help our network planners to make better decisions. This is particularly important in a more complex network with high penetration of household PV, and greater opportunities for non-network solutions.
- Assisting our transition to NER compliance in a prudent and efficient manner – We require systems to keep pace with the higher standards and expectations in the NT NER, and to meet new compliance obligations such as for metering and connections.

We have commenced the Meter to Cash program which will look to replace the Retail Management System (RMS) Meter Data Management System. The vendor has managed to combine the systems to provide Power and Water with a single system to manage its water billing, network, meter and market gateway obligations. The program has been segmented into five blocks over 24 months.

We have completed phase two of the upgrade of Geographic Information System (GIS). ESRI has been upgraded to the latest version including a new 'dial before you dig' interface.

In terms of our hardware replacement, we continue to focus on the Energy Management System (EMS) which is due to be completed in March 2022. The intent is to ensure the system is on supported hardware whilst we plan for the software upgrade.

Power and Water has also improved its reporting capability over the last year by commencing two key projects. The data historian (OSI Pi) has been implemented to improve data collection from the EMS. The project will improve the reliability and access to network data. The second project has focused on improving reliability and automation of the annual data we report to the Australian Energy Regulator in our Regulatory Information Notice.

Power and Water has also improved its reporting capability over the last year by commencing two key projects.

5. Asset management

Power and Water has a comprehensive asset management framework that reflects a 'whole of lifecycle' approach to efficiently manage our assets. As part of the framework, we undertake regular planning reviews to identify emerging system limitations and solutions. A key focus of our planning is working with stakeholders to identify lower cost non-network solutions to address limitations.

The purpose of this section is to describe our planning framework for maintaining assets and investing in new or replacement assets. We provide a brief outline of our key network planning obligations, describe our asset management system, and set out our process for identifying investment needs and options.

5.1 Our planning obligations

Power and Water is subject to specific Northern Territory and national regulations that direct and influence the way we manage, operate and plan our network. The key planning obligations that directly influence our planning decisions are described below.[5]

Network Technical Code and Network Planning Criteria

Power and Water must comply with an obligation under the Northern Territory Electricity Reform (Administration) regulations to publish a Network Technical Code and Network Planning Criteria. In March 2020, we published a document which combines the two requirements.[6]

Our planning decisions are also based on other regulation such as corporate responsibility, worker safety, and the environment. Further we have a regulatory obligation to adhere to good electricity industry practice when providing network access services and in planning, operating, maintaining, developing and extending the electricity network.

The Network Technical Code sets out network performance criteria including frequency, quality of supply, stability, load shedding, reliability, steady state criteria, and safety and environmental criteria.

It also sets out power system security requirements. The Network Planning Criteria identifies the supply contingency criteria that we must use to plan and operate our network. The criteria relate to:

- Supply contingency – This is the ability of the supply system to be reconfigured after a fault (contingency) so that supply to customers can be restored.
- Steady state – This is the adequacy of the network to supply the energy requirements of users within the equipment ratings, frequency and voltage limits, taking account of planned and unplanned outages.
- Stability – This is to ensure the power system can return to a steady-state or equilibrium operating condition following a disturbance.
- Quality of supply criteria – This relates to operating the system within the acceptable voltage and current ranges.

[5] The documents can be accessed on our website at: https://www.powerwater.com.au/developers/power/technical-code-and-planning-criteria.

Zone substation, Katherine.

Northern Territory Electricity Industry Performance Code (EIP Code)

The EIP Code applies to our regulated networks of Darwin-Katherine, Alice Springs and Tennant Creek. The Code influences the way we plan the network to achieve reliability targets and address worst performing feeders on our network.

The EIP Code required us to propose reliability performance targets to the Utilities Commission for the 2019-24 regulatory period. The targets are based on System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) performance standards. SAIDI is an index showing the length of time customers are without power and SAIFI is an index showing the frequency of power interruptions to customers. The Utilities Commission approved our proposed performance targets for the 2019-24 regulatory period.

The EIP Code also requires us to provide an annual report to the Utilities Commission on the five worst performing feeders for each feeder category. This includes information on the SAIDI performance on each of the identified feeders, and a statement that explains the performance and action we intend to take to improve performance.

We discussed our network performance for 2020-21, and outlined our reliability program to address reliability issues in section 4.1.

Northern Territory National Electricity Rules (NT NER)

Power and Water is subject to planning obligations under Chapter 5 of the NT NER. This includes obligations to forecast demand on elements of our network, obligations to undertake annual planning and report on outcomes, and specific obligations with respect to connecting large customers and embedded generators. Chapter 5 of the NT NER also requires us to manage, maintain and operate our network to minimise interruptions to connected customers, and restore the network as soon as reasonably practical following an interruption.

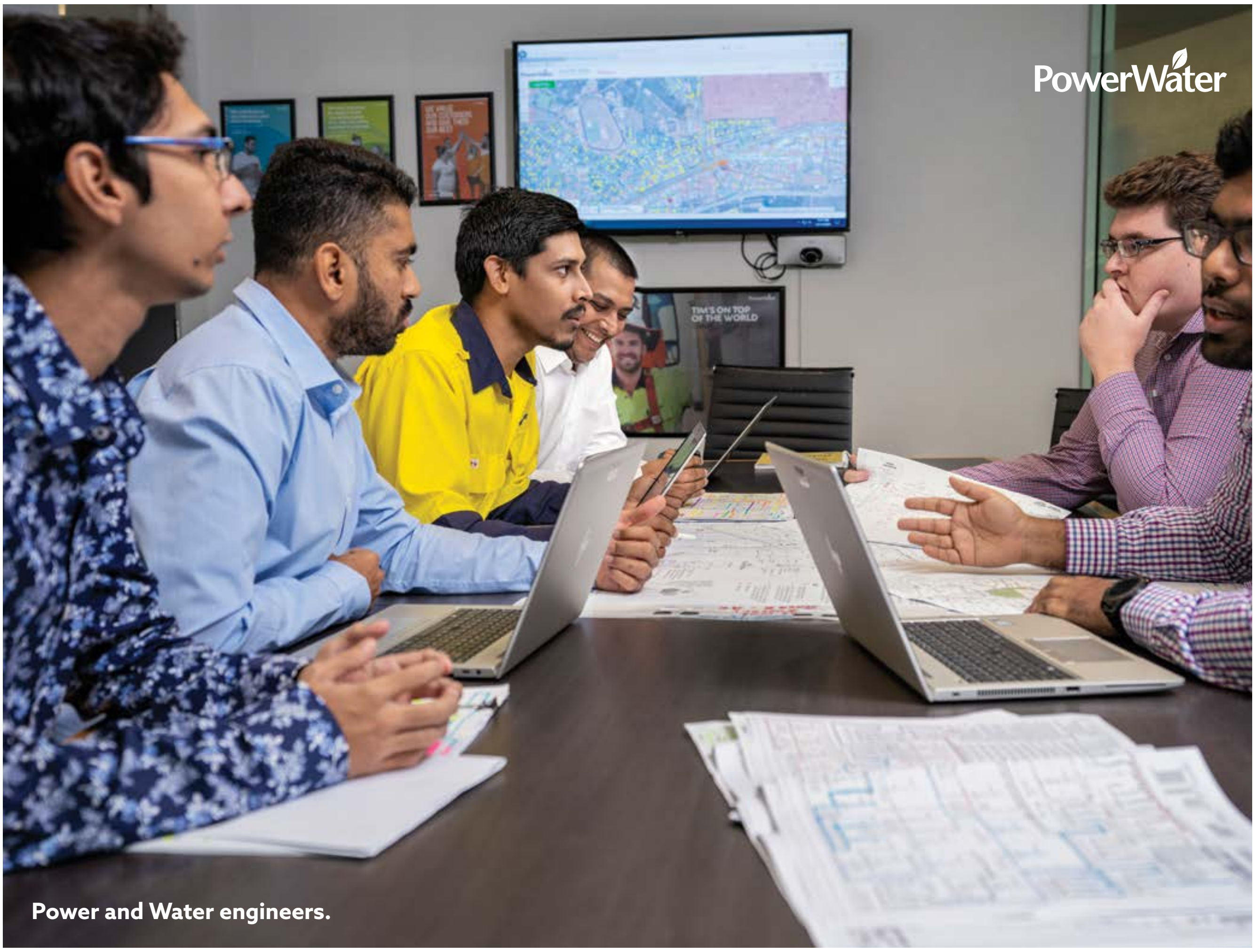
Potential new obligations

The Northern Territory Government is continuing to reform the electricity market. A key focus area is improving the efficiency of system security services (ESS) of the power system.

In its draft report in January 2021, the Northern Territory Government indicated that Power and Water will likely have responsibility for locational voltage and system strength requirements. We will report back to customers in next year's TDAPR on how the new framework will impact Power and Water's planning and capital forecasts.

We also note that the Australian Government is consulting on reforms to critical infrastructure legislation. This is likely to impact both our network communication and ICT systems, but we are awaiting the completion of the reform program.

The Northern Territory Government is continuing to reform the electricity market.



Power and Water engineers.

5.2 Improvements to our planning

Power and Water is currently implementing significant changes to our approach to capital planning.

In Chapter 3, we noted that we are working towards a Future Network Strategy that helps us plan for three key challenges – integrating renewables, managing ageing assets, and facilitating electric vehicles efficiently.

In addition, we are making three key changes to our planning approach.

Strategic area planning

Area planning provides an opportunity to efficiently design the network to address multiple drivers of investment . For example, in Darwin-Katherine we expect large industrial and housing developments to emerge over the next 20 years. This may require an expansion of zone substations and our transmission network.

Area planning will help us identify the macro drivers in each of our three networks, so we can develop a long-term view of the optimal development of the network.

Demand forecast process

We are currently updating our demand forecast methodology to generate more accurate forecasts of solar installation and connections. We will also be able to forecast minimum demand at the zone substation, which occurs on days when there is high solar production but low demand from customers.

For this year's TDAPR we have continued to apply our current methodology. Over the next six months we will seek feedback from a broad range of stakeholders on our approach. Chapter 6 provides more detail on our demand forecasts.

Risk quantification

Power and Water is developing a quantitative risk framework to consistently rank risk across our assets. The framework will help us to develop capital programs that balance affordability and network performance.

Risk quantification identifies the probability of asset failure and its consequence in dollar terms. We are currently developing a value framework for risks, and an accompanying model. We hope to discuss our approach with customers over the next six months.

Applying the new framework may lead to changes in the project scopes, timing and volumes identified in this year's TDAPR.

Poles, Alice Springs.

5.3 Asset management framework

Our asset management strategy seeks to efficiently provide a safe, secure and reliable electricity network service to our customers.

To meet this objective, we develop a Strategic Asset Management Plan (SAMP) that aligns to our corporate objectives. The SAMP reflects a 'whole of lifecycle' approach to asset management through planning and design of new assets, maintaining and operating existing assets, and renewal and retirement of assets.

In the SAMP, we group our network assets into common categories including zone substations, transmission lines, distribution assets, and secondary systems. From here we develop specific asset class strategies and plans for these asset groups including maintenance and renewal.

Asset maintenance

Our maintenance activities seek to cost-effectively ensure assets remain in functional service. Routine activities include inspections, patrols, surveys, testing, repair of assets, and switching activities. Non-routine activities are predominantly directed at restoring asset condition or performance, or rectifying defects.

Our approach to routine and non-routine maintenance is based on the principles of objective need and risk management. Our goal is to optimise maintenance by prioritising activities based on asset health and criticality.

The intensity of maintenance activities for each asset class is dependent on several factors including the existing condition and performance of the assets, operating environment, location of asset, and demand profile. The appendices identify our maintenance strategies for each asset class.

Over the last decade, we have made significant improvements to our asset maintenance framework. The recent roll-out of mobile field devices for maintenance work enabled asset information to be captured and entered directly into our asset management system. This initiative has been critical to improving our understanding of asset condition and performance. The introduction of mobile devices has resulted in significant reductions in our maintenance expenditure by improving the efficiency of our preventative activities.

We are also currently reviewing and developing online monitoring techniques to improve asset reliability and maintenance efficiencies. Our inspection and condition monitoring practices have evolved and will continue to be optimised through maturing risk management practices. Our maintenance strategies are set out in the appendix to this report.

Our asset management strategy seeks to efficiently provide a safe, secure and reliable electricity network service to our customers.

Asset renewal and retirement

We apply an economic assessment framework to identify the optimal time to retire or replace assets. Our framework considers the asset's condition and failure modes, the likely risks of failure on safety, security and reliability of services to customers, and the relative maintenance and capital costs. In some cases, our decision making will be influenced by demand growth or customer upgrade requirements. Essentially, our decision making is based on an economic assessment of risks, costs and benefits.

Our approach recognises that the criticality and consequence of asset failure varies among different network assets. For this reason, we apply different strategies to our asset classes based on risk profile, capital value and criticality to maintain reliable and safe operation of the network. The replacement strategies include:

- Replace on failure (Functional failure) – This is where the asset has low criticality, and where asset condition information is difficult or costly to gather. In these cases, it is more economical to keep the asset in service provided the maintenance costs do not justify replacement.
- Condition-based (Conditional failure) – This is where the function provided by the asset is critical and the cost of risk exceeds the replacement cost. In these cases, we need a clear measure that the asset is not performing to meet the network need.
- Planned (Proactive replacement) – This is where there are emerging risks such as safety or environmental risks, change in technology, or legislative and compliance changes. In these cases, asset condition may be measurable and can be used to prioritise replacements or spread replacement activity over longer timeframes to eliminate significant spikes in expenditure and associated resources.
- Demand-driven – This is where we identify that the existing installed capacity is insufficient to supply the forecast demand. This recognises that there may be synergies in the timing of replacement to meet a demand driver.
- Customer driven – This is where the individual customer requests new or increased capacity. Similar to above, this recognises there may be synergies in retiring an existing asset in degraded conditions at the time of an upgrade.

Table 4 identifies the key replacement strategies for our asset categories. It shows that we seek to replace critical assets such as circuit breakers and transformers before failure to minimise reliability and safety consequences.

Table 4: Replacement strategies for specific asset categories

Asset class	Replace-on-failure	Condition-based	Planned	Demand-driven	Customer-driven
Circuit breakers		•	•	•	
Power transformers		•	•	•	
Distribution substations	•		•		•
Distribution switchgear	•		•		
Transmission towers		•	•		
Distribution structures		•	•		
Cables	•		•	•	•
Conductors	•		•	•	•
Services	•		•		•

5.4 Methodologies for planning the network

Under our asset management framework, we undertake regular reviews of our network to determine emerging issues and solutions. As we operate standalone transmission and distribution networks in our regulated areas, we have no joint planning requirements or activities.[7]

In 2021, we have extended the outlook from five to 10 years for our distribution network. This aligns to our outlook for transmission networks, and is a sensible approach given the need for long term planning as outlined in Chapter 3.

Our planning process seeks to identify system limitations including:

- Capacity constraints – On an annual basis, we forecast projected maximum demand for distribution feeders, zone substations, and transmission lines. The demand forecasts reflect recent trends in maximum demand, forecast major connections, and forecast major embedded generation. Our planning process considers if there is likely to be thermal constraints on our equipment with reference to the network planning criteria.
- Condition of assets – Using a risk-based approach, we identify assets that should be replaced, retired, or more intensely maintained. The condition of assets is influenced by age, previous maintenance, environmental conditions such as exposure to salt, humidity, proximity to animals, and extreme weather events.
- Quality of supply issues – We monitor power supply issues based on customer feedback, and monitoring data from meters, and zone substations. Quality of supply is impacted by a generator tripping or transmission fault, switching of network equipment such as reactive plant, installation and switching of customer loads, and embedded generation such as solar rooftop installations.
- Fault levels – We regularly review whether our assets remain within the fault levels prescribed in the Network Technical Code. Fault levels are impacted by changes in the configuration of the network particularly with the addition of generators, embedded generation, power transformers and large motors.
- Distribution losses – We monitor the extent of distribution losses on the network and identify if action is required to minimise losses.

Once a system limitation has been identified, we analyse whether it gives rise to an investment need. The first internal gateway for the creation of a project is the Business Needs Identification (BNI). The purpose of the BNI is to demonstrate the investment need and supporting evidence with reference to the risk to reliability, security or safety of services.

The Preliminary Business Case (PBC) process analyses a range of feasible options to determine the most prudent and efficient investment to meet the need identified in the BNI. We identify and analyse project risks and develop the scope and requirements for the preferred option. Depending on the value of the project, we may also develop a more detailed business case before the project is implemented. This is to ensure sufficient project analysis and development prior to seeking approval to proceed.

An integral aspect of our planning framework is to investigate whether demand management (non-network) solutions can effectively defer or avoid investment. We understand that demand management holds the key to improving affordability for our customers by reducing the cost of addressing network limitations.

After the completion of the project, we conduct a Post Implementation Review (PIR) to confirm whether the expected benefits have been delivered by the investment to inform continual improvement of the process.

[7] The NT NER requires that a network's TDAPR specify joint planning obligations and activities.

6. Demand forecasts

Power and Water has a rigorous method to forecast maximum demand on our transmission lines, zone substations and distribution feeders. Our method relies on annual reviews of recent demand data, and projections of new customer connections and embedded generation. Maximum demand is increasing across all three regions with specific locations experiencing high rates of growth due to housing and commercial developments.

Demand forecasts are a key part of our planning process, helping us establish whether any element of our network will face a capacity limitation.

We undertake an annual review of demand forecasts commencing in April of each year. The timing of the review allows us to incorporate most recent data on maximum demand which generally peaks in the October to March period. This coincides with the wet season in Darwin-Katherine and summer in Alice Springs and Tennant Creek.

Our demand forecasts are prepared on a locational basis, which are often termed 'spatial' forecasts. We prepare spatial forecasts for individual network elements including our distribution feeders, zone substations and transmission lines. The information is used to determine whether there are capacity constraints emerging on the network.

In summary, our process identifies the underlying trend in demand based on the last six years of historical data, including the most current data. We extrapolate the underlying trend and incorporate the impact of significant new connections and embedded generation. In sections 6.2 to 6.4 we explain the specific approach for distribution feeders, zone substations and transmission lines.

As noted in section 5.2, we are currently evaluating improvements to our spatial demand forecast approach. A key focus will be on improving our methods to forecast solar, batteries and electric vehicles, together with connection forecasts. We will also be extending our forecasts to minimum demand.

6.1 Regional outlook

Currently, Power and Water does not undertake demand forecasts at a regional level. We rely on data produced by the Utilities Commission of the Northern Territory in its annual Electricity Outlook Report.

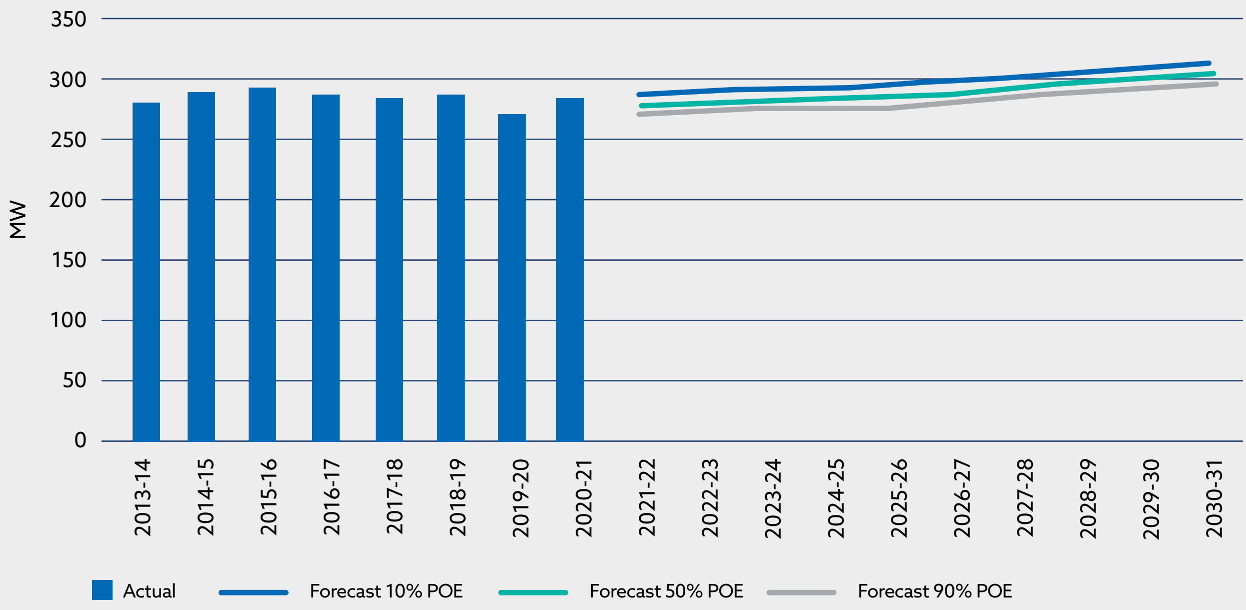
Figures 25 to **30** provide the maximum and minimum demand for Darwin-Katherine, Alice Springs and Tennant Creek as produced in the 2020 Outlook report. We have updated the data series for actual maximum and minimum demand in 2020-21.

The 2020 Outlook Report suggests that maximum demand will increase in Darwin-Katherine and Alice Springs over the next decade. This reflects a shift back to peak demand growth after a period of decline between 2015 and 2020. The report also suggests Tennant Creek's demand will be higher over the next decade, however we consider this will likely be revised down.

In all regions, the Utilities Commission of the Northern Territory is forecasting a decline in minimum demand. This largely relates to increased solar installations which reduces demand in the middle of the day.

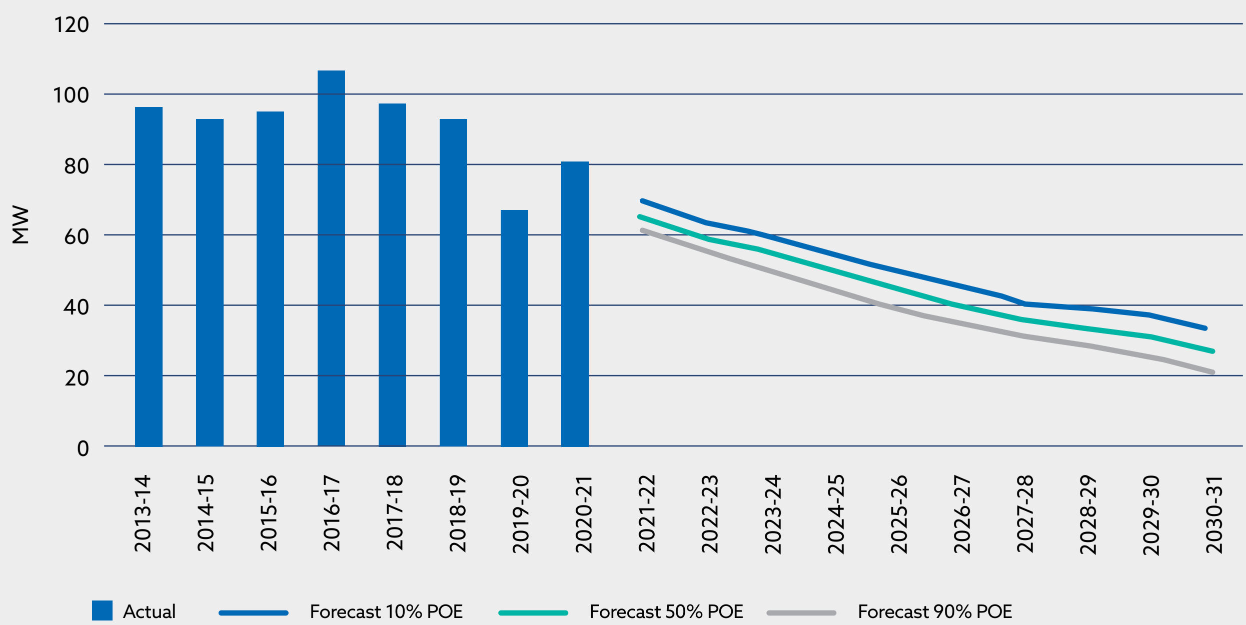
Power and Water has a rigorous method to forecast maximum demand on our transmission lines, zone substations and distribution feeders.

Figure 25: Darwin-Katherine maximum demand forecasts



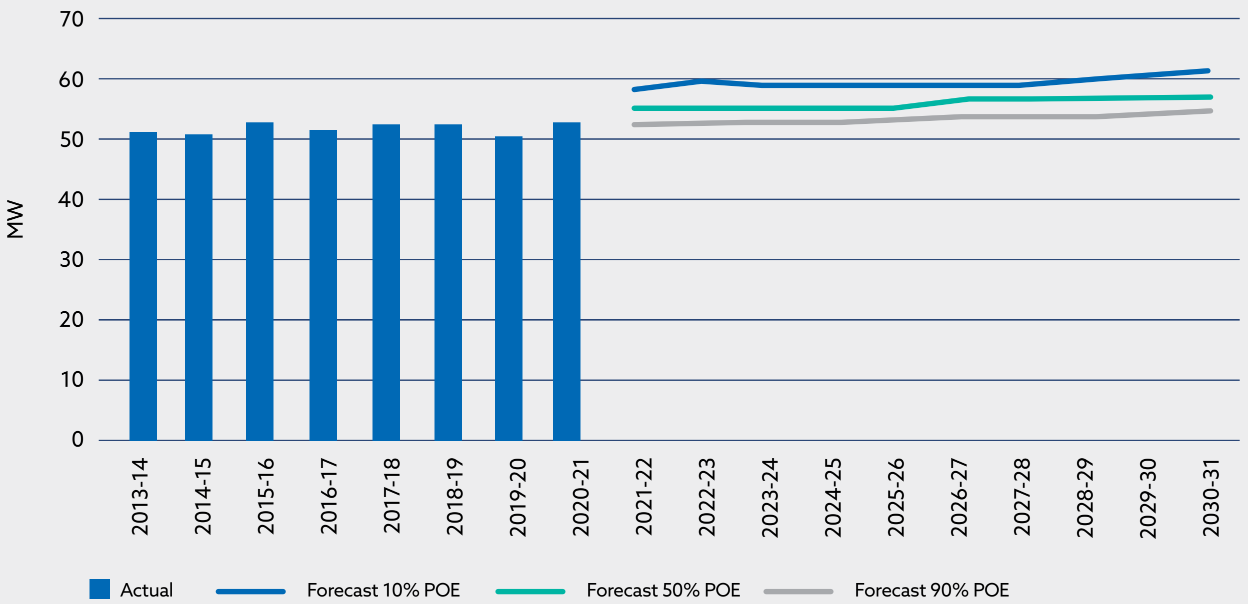
Maximum demand in Darwin-Katherine increased in 2020-21 above expectations, and is forecast to grow by close to 10 per cent over the next decade.

Figure 26: Darwin-Katherine minimum demand forecasts



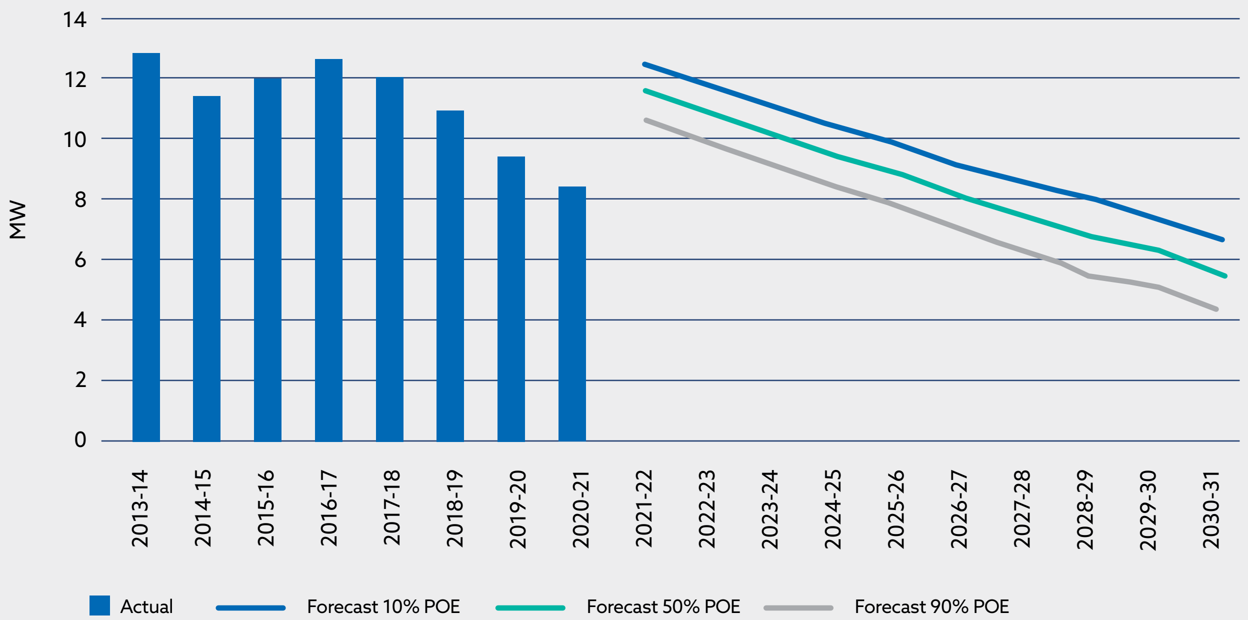
Minimum demand was above last year in Darwin-Katherine, but this is more likely due to weather. As solar installations continue to grow, minimum demand is expected to fall.

Figure 27: Alice Springs maximum demand forecasts



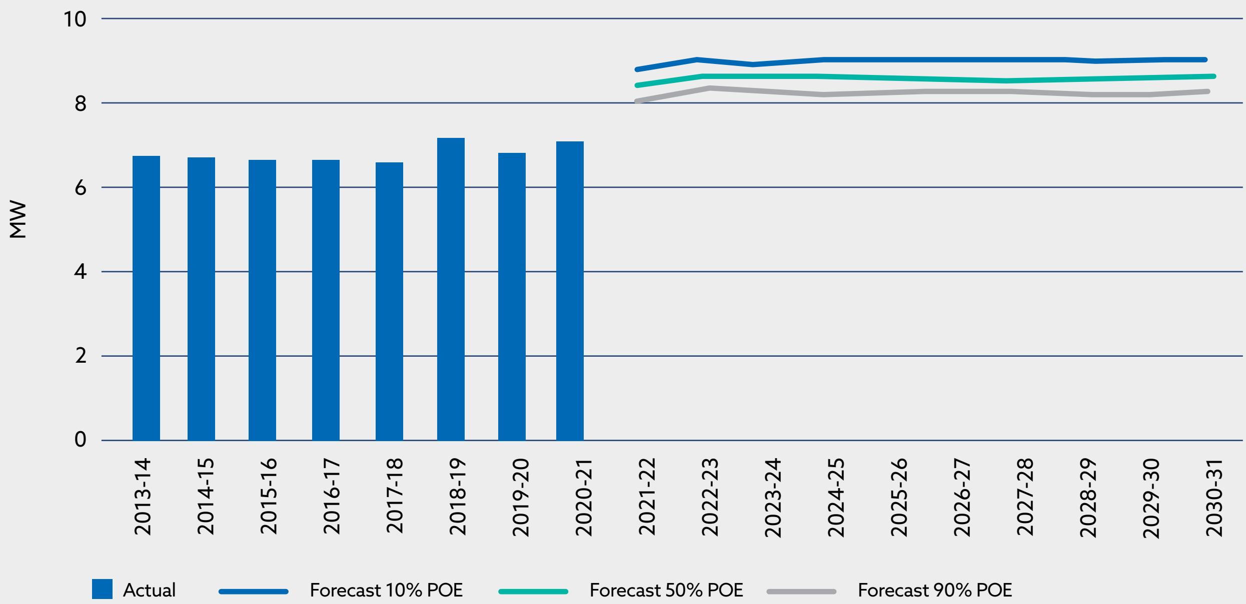
Maximum demand in Alice Springs also increased in 2020-21 and is forecast to increase over the next decade.

Figure 28: Alice Springs minimum demand forecasts



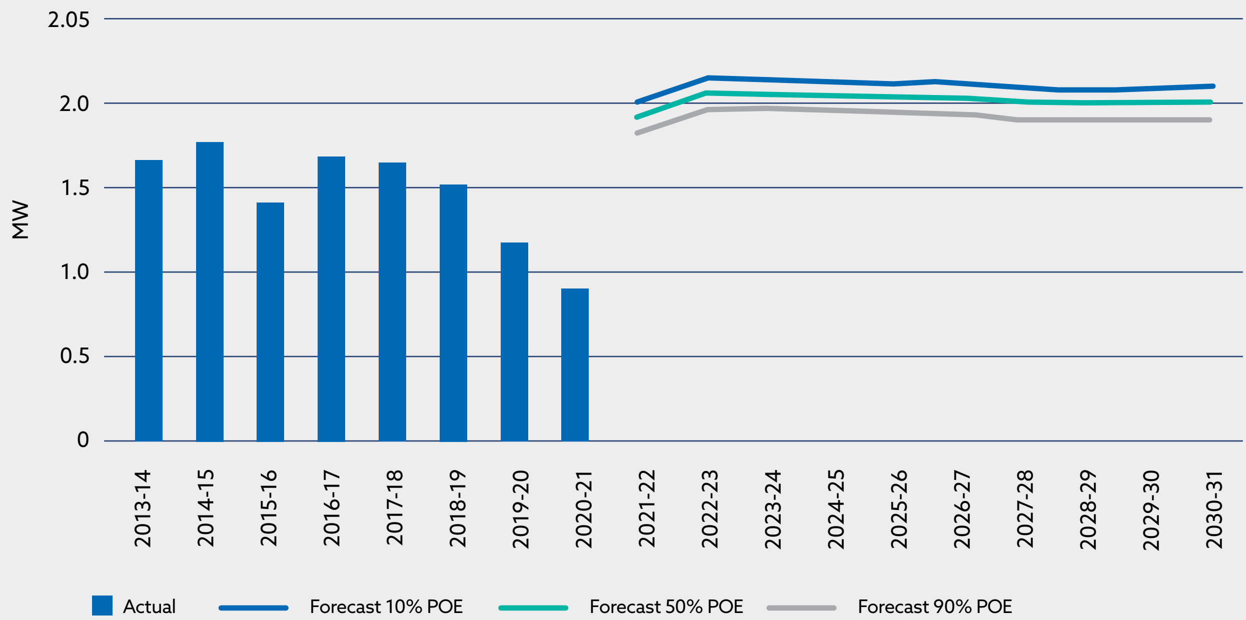
Minimum demand in Alice Springs continued to fall in 2020-21 below expectations, and is likely to fall towards zero by the end of the decade.

Figure 29: Tennant Creek maximum demand forecasts



Maximum demand in Tennant Creek is projected to be higher, but we consider this may relate to a connection that is uncertain.

Figure 30: Tennant Creek minimum demand forecasts



Minimum demand in Tennant Creek fell significantly in 2020-21 but was forecast to increase over the next decade. We consider that this may indicate that the current forecasts may need to be re-visited.

6.2 Distribution feeders

We forecast maximum demand on each distribution feeder on our network. The starting process is to identify the underlying trend in maximum demand growth on the feeder. We examine six years of maximum data including the current year to determine the linear trend in maximum demand, excluding the impact of new connections, embedded generation and temporary transfers. For 2020-21, the 'base value' relied on 30-minute interval SCADA data, which is then adjusted to remove temporary transfers and the impact of new connections and embedded generation.

Our next step is to adjust the 'base value' in 2020-21 to incorporate the impact of permanent new connections, embedded generation, and permanent transfers that occurred in that year. The underlying trend is then extrapolated from 2021-22 to develop a forecast trend for each feeder. We then add the expected load from committed new connections and subtract the load from expected large scale embedded generation. We also incorporate the impact of permanent load transfers between feeders. In this way, the method reflects the underlying trend in demand, and the expectations of new load and embedded generation.

Due to the large volume of feeders on our network, we have only identified feeders which have been forecast to experience a capacity limitation, as set out in the data appendix accompanying this report.

Only six feeders will experience a capacity issue in the next decade based on our current forecasts, and these are located on the Darwin urban network. The driver for higher demand relates to new major housing or commercial developments on the feeder. As discussed in Chapter 8, the limitations will be addressed through load transfers from adjacent feeders with spare capacity.

6.3 Zone substations

Power and Water has 25 zone substations that connect to distribution feeders. Zone substations meet the definition of the connection point between our transmission and distribution networks, as defined by the NT NER. Our forecasts for zone substations extend for ten years, with this year's TDAPR providing a forecast of maximum demand for 2021-22 to 2030-31.

We forecast maximum demand for zone substations using the general approach described for distribution feeders as set out in section 6.2. However, a key difference is that we weather correct the recorded maximum demand to normalise the impact of varying temperature across years.

The first step in our weather correction process is to record the maximum ambient temperature of the day when maximum demand occurred. This establishes a correlation between maximum demand and temperature. Weather-corrected maximum demand is based on the difference between the maximum daily temperature for each region and the assumed 50 per cent probability of exceedance (PoE) and 10 per cent PoE temperatures for the regional reference weather station.

We identify the linear underlying trend for each zone substation at 10 per cent and 50 per cent PoE using weather-corrected maximum demand for the preceding six years[8] (including the current year). We then include the impact of committed connections and embedded generation.

[8] The number of preceding years may need to be adjusted if there is a significant load increase or drop in load during a particular year.

The actual demand for 2020-21 and forecasts to 2030-31 for each zone substation are set out in the databook appendix accompanying this report, together with information on existing capacity under different contingencies. The information identifies the zone substations where a system limitation has occurred under a 10 per cent and 50 per cent POE forecasts.

There is a material difference in our demand forecasts compared to last year, largely driven by our expectation of connections in particular areas.

6.4 Transmission lines

Power and Water has transmission lines in Darwin-Katherine and Alice Springs that transport generation to our zone substations. We forecast demand on transmission lines for a period of 10 years. For this year's TDAPR the forecasts are for 2021-22 to 2030-31.

Our forecast method relies on zone substation and generation connection point forecasts. Our approach is to use the 50 per cent POE zone substation forecasts described above, with an adjustment for load diversity. We also forecast generation at each of the existing and new connection points to the transmission network, together with any new load connecting to the transmission network. We also undertake contingency analysis of our transmission lines.

The databook accompanying this report sets out demand forecasts for our transmission lines and the results of our contingency analysis. There are no material changes from last year. Section 8.1 identifies the capacity limitations we have identified for transmission lines based on our 10 year forecasts.

Distribution feeder, Katherine.

7. Programs to address asset condition

Replacing our ageing network assets will be the primary driver of capital expenditure over the next decade. A large cohort of our network assets will be over 50 years by 2025, which indicates that more corrective maintenance and replacement will likely be required. Our asset management planning is directed at keeping these assets in service through targeted maintenance and robust risk management. Our targeted programs will replace assets that pose material reliability, safety or environmental risk. We have also applied age based modelling to forecast the volume of assets likely to fail in service.

In this section we identify system limitations related to asset condition. When our network assets fail they can lead to outages, safety incidents and environmental issues.

As noted in Chapter 3 of this document, our historical rates of replacement have been very low across all asset classes. This reflects that our assets are still relatively young, and that our maintenance and targeted programs have led to good reliability performance.

However, looking out to 2030 we see that more of our assets will be at, or approaching the end of their technical life. In part, this is due to the wave of asset investment in the wake of Cyclone Tracy in 1974. **Figure 31** shows that we forecast significant ageing in our assets by 2030 indicating a need to lift replacement rates from today's low levels.

In developing a forecast of replacement to 2030, we have continued our practice of deferring replacement until absolutely required.

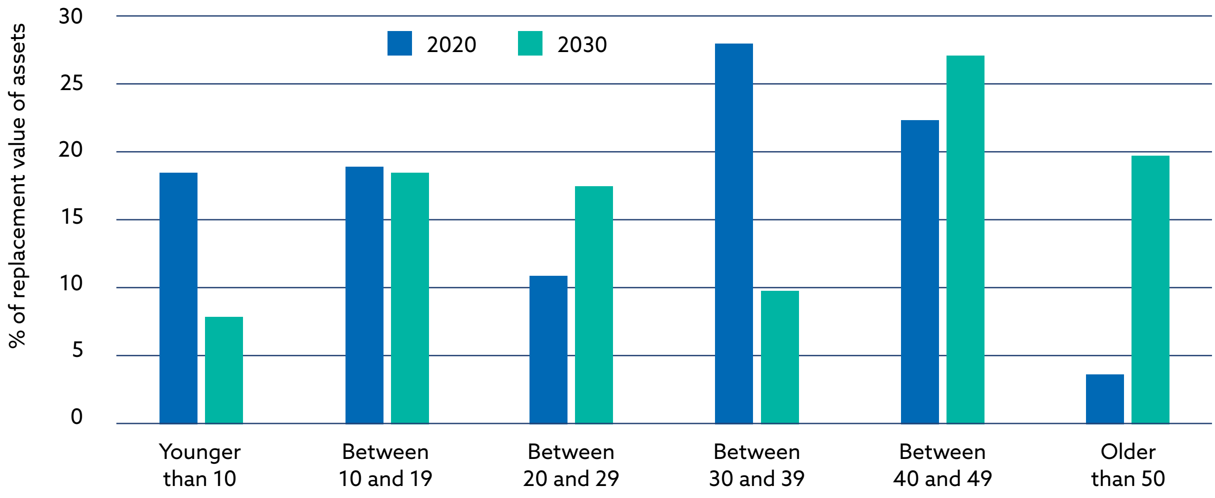
Our targeted projects and programs look to replace assets in poor condition before they fail, based on an assessment of the reliability, safety and environmental risks. **Figure 32** shows that most of our planned replacement expenditure will be on zone substations and underground cables over the next decade. As noted in Chapter 5, we will be using more sophisticated risk quantification tools ahead of next year's TDAPR to improve the consistency and precision of risk calculations.

For this year's TDAPR, we have also developed an age-based model of likely asset failures to 2030, assuming the targeted programs are in place. Our modelling suggests that our networks will continue to age despite our targeted programs, and this will result in considerably more assets failing in service.

We will continue to explore options to address asset condition, including non-network alternatives and look forward to stakeholders offering ideas we have not considered.

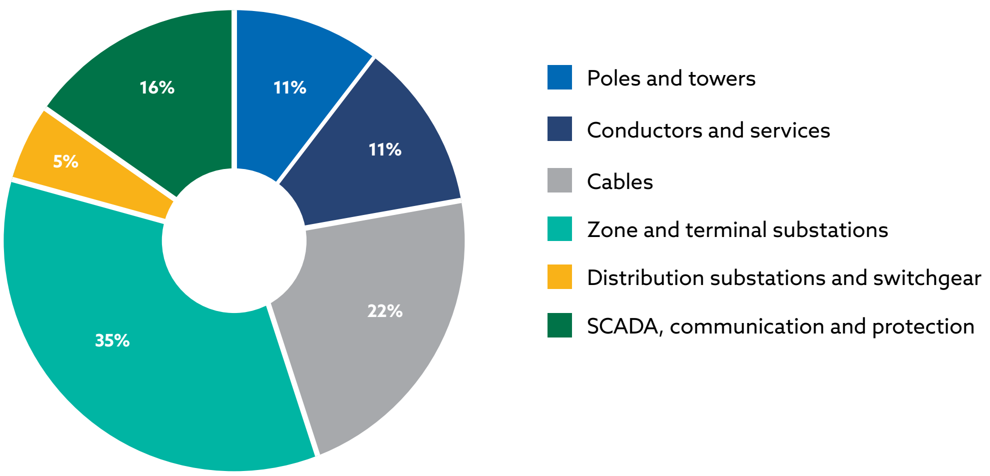
Our targeted programs will replace assets that pose material reliability, safety or environmental risk.

Figure 31: Asset age profile in 2020 compared to 2030



Based on current replacement rates, we expect the network to significantly age over the next decade.

Figure 32: Breakdown of planned projects and programs by asset class over the next decade



Most of our targeted replacement programs will be on large substations, together with underground cables.

7.1 Transmission towers and poles

Power and Water has about 3000 transmission towers and 42,000 poles across our regulated network as seen in **Figure 33**. These assets keep our overhead wires (conductors) at a safe height clearance from the community.

Due to the harsh environment, Power and Water relies on steel as the primary material in our poles and towers. The dominant cause of failure of steel poles and towers is corrosion due to water and wind exposure.

Below we have identified asset condition limitations which give rise to a targeted program over $5 million across the 10 year planning horizon. We have also identified minor programs and the estimated replacement volume of other poles and towers based on high level modelling.

Alice Springs corroded poles ($17 million)

The major targeted program for pole replacement and refurbishment is at Alice Springs. The poles are corroded from high salinity and moisture levels in the soil. We plan to replace and refurbish about 200 poles each year for the next decade.

A high proportion of poles between the ages of 30 and 50 years have corrosion issues. This causes structural integrity issues, leading to safety risks to the public and our field crews if the pole falls.

We will be targeting replacement and refurbishment of the poles that are in worst condition and pose highest risk to the community. The project will be ongoing for the next decade due to the high volume of degraded poles.

There are no non-network alternatives that we have identified in our planning process.

Darwin transmission tower programs ($12 million)

There are three targeted programs for transmission towers on the Darwin-Katherine transmission network.

Our transmission towers are subject to extreme weather which has resulted in significant corrosion issues for assets over the age of 40. Our options analysis identifies refurbishment as lower cost than replacement. The solution is to re-apply protection to the galvanised steel. We expect to remediate about 70 transmission towers, commencing in 2025 and continuing to 2029.

We also have a program to address earthing issues with our transmission towers. Earthing mitigates voltage issues when lighting hits a transmission line. Our analysis suggests the earthing is not performing due to physical damage and corrosion. Our options analysis identifies refurbishing the tower earthing components as the least cost option. The project is expected to continue past 2024.

The final targeted program relates to addressing corrosion issues with insulators on cross arms. This is apparent on the 132kV Channel Island to Hudson Creek line and the 66kV Weddell to Strangways line.

This creates a safety risk for our staff working near the asset and for the public located close to the asset. Further, the assets are crucial for the security of the network. Based on our options assessment, we have already commenced replacing the degraded assets and will continue until 2029.

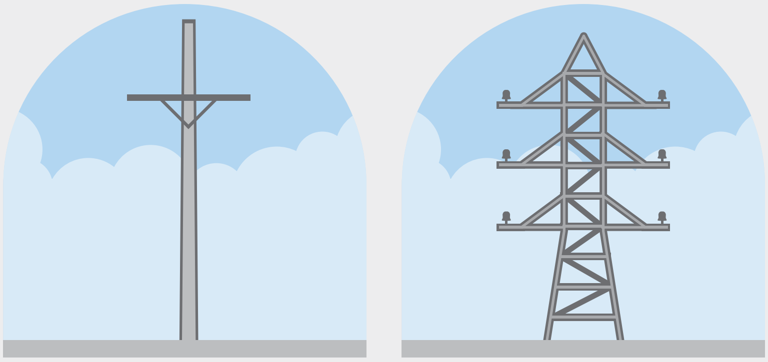
Non-targeted replacement volumes

In addition to the targeted program, we expect to replace significantly more poles and towers as can be seen in **Figure 34.** Our high-level modelling has excluded asset populations which are subject to targeted replacement.

The findings suggest that poles and towers will significantly age over the next 10 years despite our targeted program, indicating higher levels of replacement will be required. We expect that our regular inspection program will be able to identify assets at risk before they expose the community to safety issues.

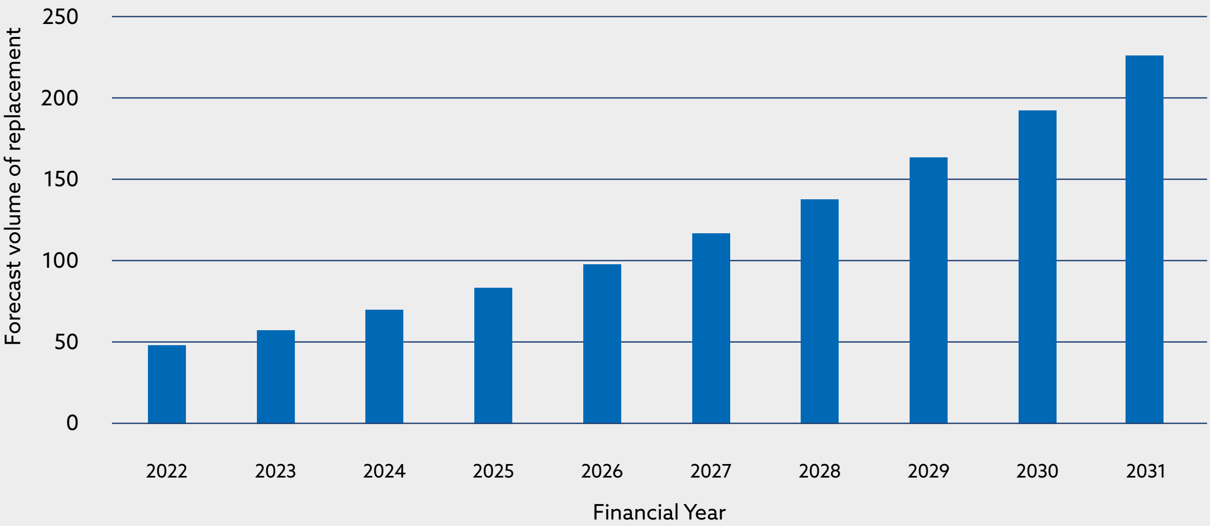
Poles, Alice Springs.

Figure 33: Information on poles and towers



Asset Category	Darwin-Katherine	Alice Springs	Tennant Creek	Total
Transmission towers	2,781	217	0	2,998
Distribution poles	32,232	6,244	3,221	41,697

Figure 34: Forecast volume of pole replacements (excluding targeted programs)



7.2 Conductors and services

Conductors are the infrastructure which transports electricity above ground. Service lines are the final point of connection to a customer's premises.

Figure 35 shows that we have about 5,100 kilometres of overhead conductors and 56,000 service lines.

Below we have identified asset condition limitations which give rise to a targeted program over $5 million. We have also identified minor targeted programs, and estimated replacement volume of other conductors using high level modelling.

We generally replace portions of conductors. This limits opportunities for non-network alternatives. For service lines, the only viable non-network alternative is off-grid.

Darwin – Lake Bennett clearance ($9 million)

The Lake Bennett feeder is located south of Darwin and extends 40 kilometres. The feeder does not comply with ground clearance regulations particularly on road crossing spans. There is also a history of defects including burnt conductor, broken strands and conductor corrosion.

Based on our options analysis, the preferred option is to install over 335 new poles between sections of line to raise the clearance height.

The program has already commenced and will conclude in 2027.

All networks – Small gauge conductor ($7.1 million)

This is a new program that was not in last year's TDAPR. We have identified a need to replace about 13 kilometres of small gauge conductor, and other parts such as connectors and joints.

The assets are approaching 60 years of age and demonstrating evidence of asset degradation. Further, spare parts are no longer being produced by manufacturers.

There is a high risk of the conductor breaking at or near poles where heating occurs, which could result in live wire on the ground. The assets are also the backbone of supply to the remote areas in Tennant Creek.

The project is still under assessment with further detailed analysis underway. At this stage the program may commence in 2025.

Darwin – 66kV transmission clearance ($6 million)

This is a new project that was not included in last year's TDAPR. The transmission line connects Strangways to Humpty Doo in Darwin's rural areas.

An aerial survey has identified a significant number of low conductor spans on the transmission line. We are currently assessing the compliance risks, and estimate that more than 50 spans will need to be addressed commencing in 2022 and extending to 2029.

The likely option to address the clearance issue is to move existing poles and install intermediate poles to raise the conductor height. However we may also need to explore increasing pole height, tightening conductors or undergrounding.

Darwin – Service lines ($7 million)

This is a new targeted program that was not in last year's TDAPR. A high proportion of our services lines are at end of life, and some are likely to have defects requiring immediate replacement.

Following a recent field inspection, we have initiated a program that will inspect all services every five years and complete necessary replacements. At this stage, we have no data to support volumes but a high level estimate is that about 4,000 Darwin service lines will need to be replaced from 2025 to 2030 and beyond. We will provide further information in next year's TDAPR.

Minor programs ($2.5 million)

We have also forecast an additional $2.5 million to address compliance issues with clearance height on conductors, based on historical trend data.

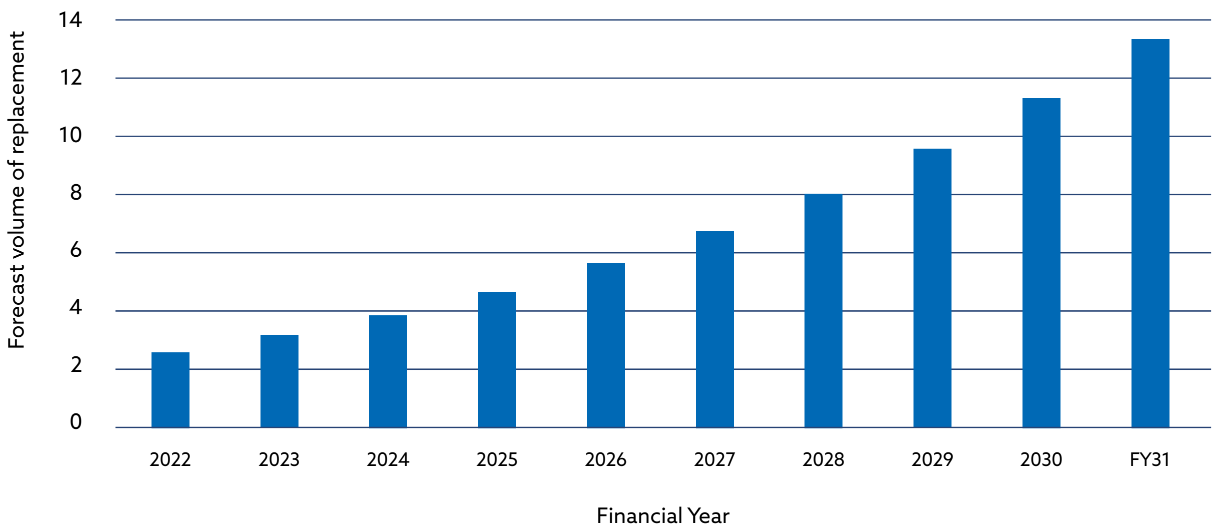
Non-targeted replacement volumes

In addition to our targeted program, our age-based modelling suggests that we will need to replace significantly more kilometres of conductors over the next 10 years, as seen in **Figure 36**. This is due to the ageing of conductors with a significant proportion older than expected age.

Figure 35: Information on conductors and services

Asset Category	Darwin-Katherine	Alice Springs	Tennant Creek	Total
132kV overhead (km)	354	0	0	354
66kV overhead (km)	339	33	0	372
Distribution feeder – overhead (kms)	2,610	509	355	3,474
Low voltage – overhead (kms)	1,012	129	44	1,185
Service lines – residential	38,712	7,067	1,047	46,826
Service lines – commercial	8,151	1,032	291	9,474

Figure 36: Forecast volume of conductor replacements (km, excluding targeted programs)



7.3 Cables

Underground cables are wiring infrastructure constructed below ground often through ducts or tunnels. We have about 1,600 kilometres of underground cable as seen in **Figure 37**.

Below we have identified asset condition limitations which give rise to a targeted program over $5 million in the 10 year planning horizon. We have also identified minor programs, and the estimated replacement volume of other cables based on high level modelling.

Similar to conductors, we generally replace segments of underground cables. This limits opportunities for non-network alternatives.

Darwin Northern Suburbs HV cable ($34 million)

Our asset investigations have shown that the sheath of some segments of cable are damaged, allowing water ingress which has caused deterioration of the cable's internal components.

The result is water-treeing which reduces the insulation integrity, while the moisture also accelerates corrosion of the neutral screen.

Eventually, the water-treeing leads to the XLPE insulation failing which causes a fault to ground. The corroded screens will increase the risk of electric shock and adversely affect our protection systems.

This exposes our workers and the public to safety risks. The program has already commenced but will uplift from 2022 to 2024 where we will replace about 40 kilometres, and replace about six kilometres each year from 2025 to 2030.

Casuarina to Leanyer 66kV Transmission ($9 million)

This is a new project that was not included in last year's TDAPR. About 2.5 kilometres of vintage XLPE cable is approaching end of life and expected to be in poor condition.

The need to replace the cable is still being assessed with further investigations underway to test condition. We will update our stakeholders with further information in next year's TDAPR.

East Arm – replacement of feeder ($6 million)

In last year's TDAPR we identified the need to replace an underground cable that runs from Berrimah zone substation to East Arm. While the cable is younger than its expected life, the original installation of cable joints was poor, which has led to severe insulation issues. The cable has a high cost of repair together with increased fault restoration time. Our risk analysis demonstrates that replacement of the cable is the most prudent and efficient option.

The project will commence shortly targeting the highest risk portions of the cable (about three kilometres) by 2024. From 2025 to 2029 we will replace the remaining portion which has continued to deteriorate.

Minor programs

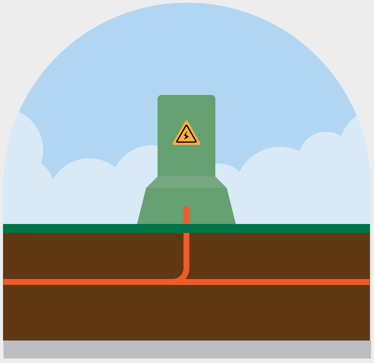
We also have three other minor cable programs that are less than $5 million. This includes:

- Darwin to Frances Bay 66kV Transmission cable ($4.5 million) – This is a new project that was not included in last year's TDAPR. The cable is an old oil-filled construction and is approaching its expected life. While only 0.75 kilometres in length, it has high costs due to its location in an urban setting. The need arises in 2029, so we have not progressed our options analysis.
- Darwin Cullen Bay to Bayview ($3.9 million) – The cables have insulation issues from water ingress and the neutral conductor in Cullen Bay is also compromised, posing a safety risk to our workers and the community in the area. Further, the deterioration issues increase the risk of asset failure. Our options analysis identified that a targeted replacement of high-risk segments of cable was the solution that efficiently and prudently managed the risks.
- Darwin CBD cable tunnel ($1 million) – This is a new project that was not included in last year's TDAPR. The tunnel is critical to supplying the CBD. Access is difficult and the condition has deteriorated due to ageing. The rusting of cable trays pose a risk to workers. The project timing is estimated to be 2027. We are currently undertaking a detailed inspection to ensure that the lowest cost scope is implemented.

Non-targeted replacement volumes

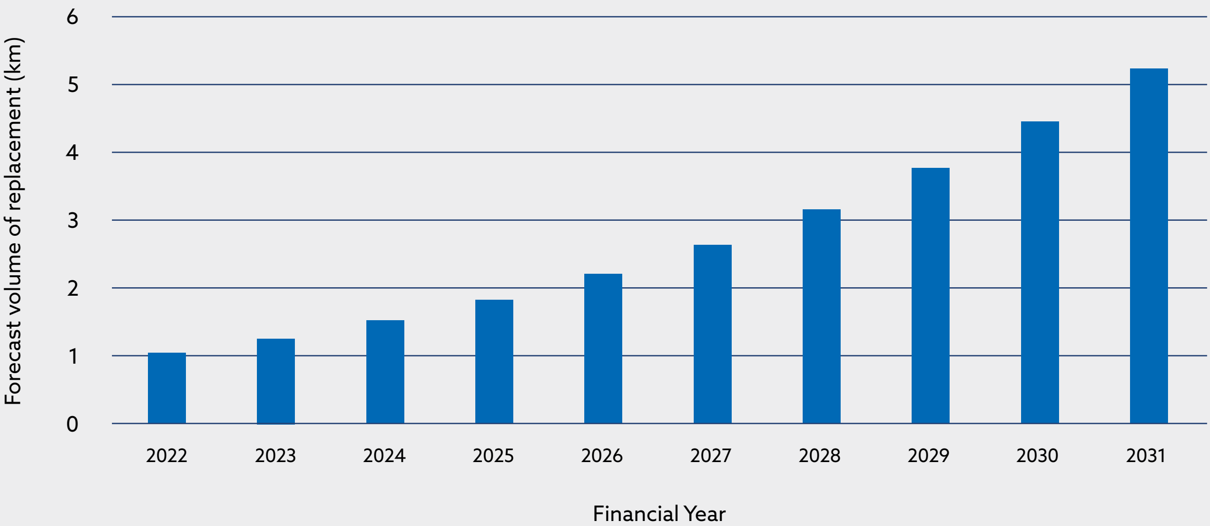
In addition to our targeted program, our aged based modelling suggests that we will need to replace significantly more kilometres of cable over the next 10 years, as seen in **Figure 38**. This is due to the ageing of cables with a significant proportion older than expected age, even accounting for the targeted programs.

Figure 37: Information on underground cables



Asset Category	Darwin-Katherine	Alice Springs	Tennant Creek	Total
132kV underground (kms)	0	0	0	0
66kV underground (kms)	25	14	0	39
Distribution feeder – underground (kms)	768	97	3	868
Low voltage – underground (kms)	596	98	1	695

Figure 38: Forecast volume of cable replacement (km, excluding targeted replacement)



7.4 Sub-transmission and zone substations

Power and Water's transmission network transports energy from our large-scale generators to large substations that transform voltage down to 22kV or 11kV. **Figure 39** identifies where our sub-transmission and zone substations are located in our regulated network.

Below we have identified material targeted programs with a value of over $5 million. We have also identified minor programs.

Darwin-Berrimah zone substation ($30 million)

We have commenced work on replacing the Berrimah zone substation and expect to complete the work by 2024.

The assets in Berrimah zone substation are at the end of their serviceable life. The 66kV oil circuit breakers are in poor condition and have a high risk of explosive failure. Our workers have also encountered safety issues with the 11kV switchboard.

Our options analysis found that building a new greenfield zone substation in an adjacent location is the least cost option to address the issues at Berrimah zone substation.

Darwin-Palmerston zone substation ($9 million)

This is a new project that was not included in last year's TDAPR. The timing for the project is estimated to be 2029.

We will be replacing assets within the zone substation but retaining those which are still in good condition.

Our analysis indicates a need to replace two of the three transformers based on testing of residual insulation strength. Three of the buses on the switchboard are approaching end of life. We also see a need to replace some of the protection and SCADA due to age. The switchgear building is also deteriorated and will need to be refurbished.

At this stage, we are still examining options in detail. A key consideration is whether there may be other solutions that help address potential capacity limitations from new land development in the area. We will report back to stakeholders in next year's TDAPR.

Darwin – Channel Island 132kV GIS circuit breakers ($9 million)

We have 14 outdoor circuit breakers at Channel Island. The switchgear is critical to ensuring secure power from our largest generation point.

The assets are currently undergoing refurbishment to ensure we can keep the asset in service. The refurbishment will likely conclude in 2025.

The switchgear has recently had some significant SF6 gas leaks which pose a high environmental risk. At this stage, replacement would need to commence in 2031. However there may be alternatives to re-investment given the expected retirement of significant generation at Channel Island.

Darwin – Upgrade transmission secondary systems ($7 million)

The Darwin-Katherine Transmission line is the main supply for the townships of Pine Creek and Katherine.

The secondary systems in the terminal substations on the line at Manton, Batchelor, Pine Creek and Katherine have exceeded their operational life and technical support. The equipment is experiencing increasing failures, and without support are technically and economically difficult to repair. This has led to a high number of unplanned outages.

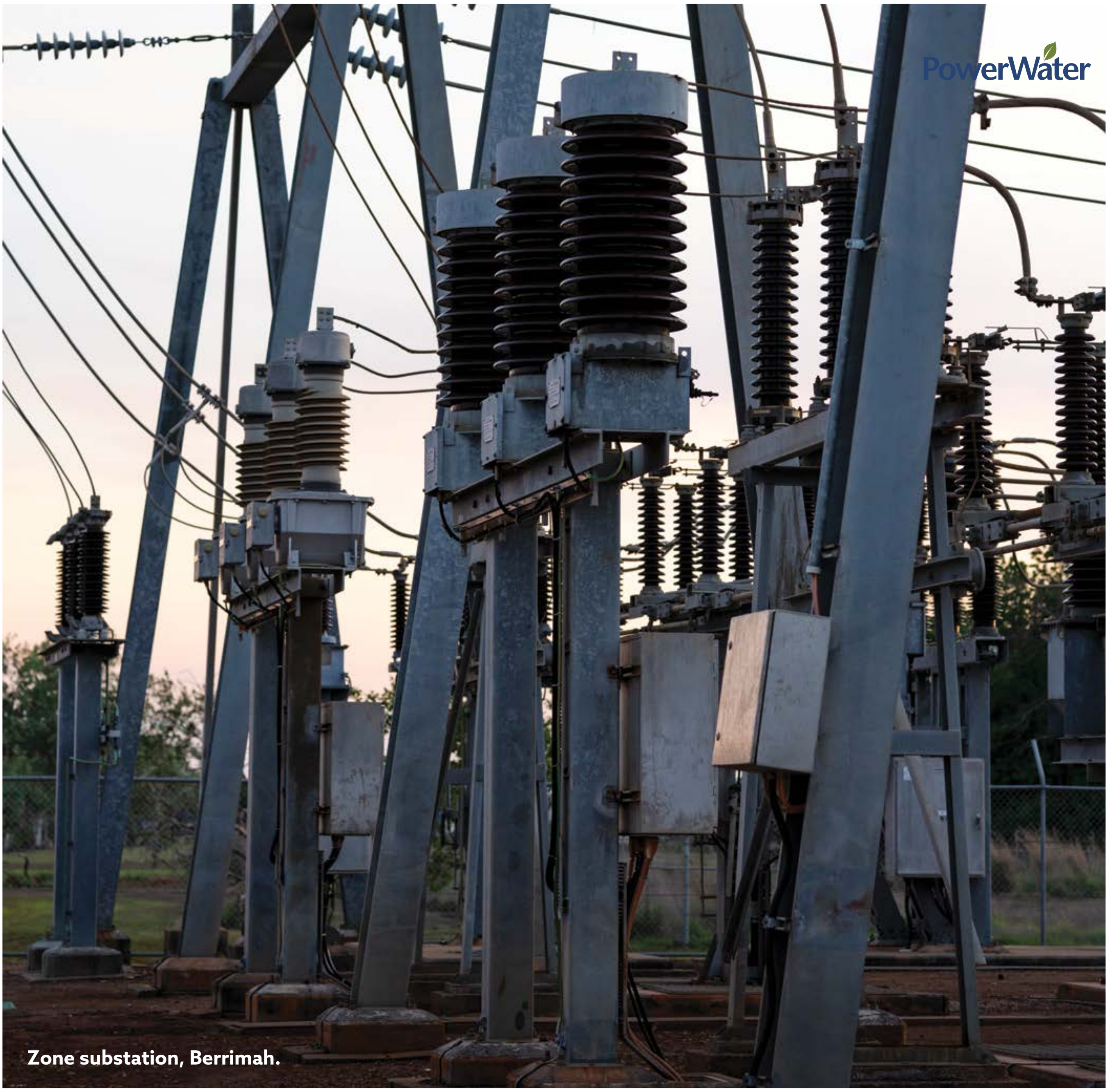
Our analysis identified replacement as the most economical option. We did not identify any viable non-network options. Work has already commenced and will be complete by 2024.

Darwin – Upgrade Humpty Doo zone substation ($6 million)

There are condition issues with the assets within the zone substation including the 66kV circuit breaker which has a history of failures associated with the operating arm, and the power transformers which have an excessive level of moisture in the paper insulation largely due to significant continuous oil leaks.

There are also condition issues with the 22kV switchgear including gas leaks, and the secondary systems are obsolete and spares are difficult to source. We were not able to identify any non-network alternatives to replacement of the assets.

We also note that there is a concurrent capacity limitation as noted in Chapter 8, and uncertainty on whether the expected load will increase in the area. Over the next year we expect to develop a much better understanding of the capacity needs in the area and will report back to our stakeholders in next year's TDAPR.



Zone substation, Berrimah.

Figure 39: Information on zone and terminal substations

Asset Category	Darwin-Katherine	Alice Springs	Tennant Creek	Total
Sub-transmission substations	3	1	0	4
Zone substations	22	3	1	26

Alice Springs – Lovegrove zone substation ($5 million)

This is a new project that was not identified in last year's TDAPR. Transformers 1 and 2 of the zone substation are approaching end of life based on measures of residual insulation strength. The 11kV switchboard (SBV2 type CBs) will be 42 to 44 years old in the planned year of replacement. All associated protection and SCADA will also need to be replaced.

We will report back on our options assessment in next year's TDAPR. At this stage replacement works for the transformers and 11kV switchboard would be required by 2026.

Minor programs

Minor programs include:

- Miscellaneous zone assets ($9 million): This is a forecast of miscellaneous condition and compliance-based replacement of individual assets such as circuit breakers and instrument transformers.
  The forecast is based on the average of historical volumes and expenditure after removing assets that will be included in other projects and programs.
- Alice Springs - Replacement of Sadadeen 22kV switchboard $(4 million): The indoor circuit breakers are aged and in poor condition. There have been several component failures including a major busbar fault. The project timing is 2025.
- Darwin – Mitchell Street circuit breakers ($2 million) – These circuit breakers are critical for supply of commercial and apartments. The assets are approaching the end of their expected lives. The project timing is 2027 but we are currently assessing the need, and preferred options. There may be opportunities for an alternative to a like for a like replacement, which we will report in next year's TDAPR.
- South Darwin – Transformers ($3 million) – The transformers are approaching 60 years and experiencing numerous oil leaks and deteriorating insulation. Our options analysis has identified a lower cost option than a like for like replacement, by having a single transformer and a nomad (mobile substation) connection in case the transformer fails. The project has already commenced and will end in 2025.
- Darwin – Cox Peninsula circuit breakers ($2 million) – The Cox Peninsula area is currently serviced by an undersea cable. The circuit breakers at the zone substation are at risk of failure due to their age and are not supported. In addition, the insulation on the transformers are compromised with numerous oil leaks. We are still examining non-network alternatives to replacement of the zone substation, and will report back to customers in the next TDAPR. The timing of the project is likely 2023.
- Substation DC replacement ($2 million) – This is a continuation of an existing program to ensure ongoing functionality and condition of the zone substation battery systems. The program will be ongoing beyond 2030.
- Substation fire equipment ($1 million) – This is a continuation of the existing program to ensure ongoing functionality and condition of the fire suppression systems. The program will continue until 2030.

Zone substation, Humpty Doo.

7.5 Distribution substations and switchgear

Distribution substations convert voltage from 11kV and 22kV feeders to low voltage. **Figure 40** shows that we have about 5000 distribution substations. The switchgear allows operators to turn sections of the network off to allow planned maintenance and emergency repairs.

Below we have identified asset condition limitations which give rise to a targeted program over $5 million in the 10 year planning horizon. We have also estimated replacement volume of other distribution substations and switchgear based on high level modelling.

Darwin – Underground substations ($7 million)

Many of our underground distribution substations are approaching end of life. The most common failure mode is corrosion at the bottom of the transformer tank, which accelerates the corrosion of the substation.

There are safety risks to the public from corrosion, particularly given the assets are located near the front yards of properties. Our options analysis indicated that a targeted replacement and refurbishment program minimised safety and reliability risks. The project has already commenced and will be ongoing beyond 2030.

Distribution pillars replacement ($6 million)

This is a new targeted project that was not included in last year's TDAPR. The pillars are deteriorating and resulting in safety issues for workers and the public. Further, easy access to the pillars has led to vandalism.

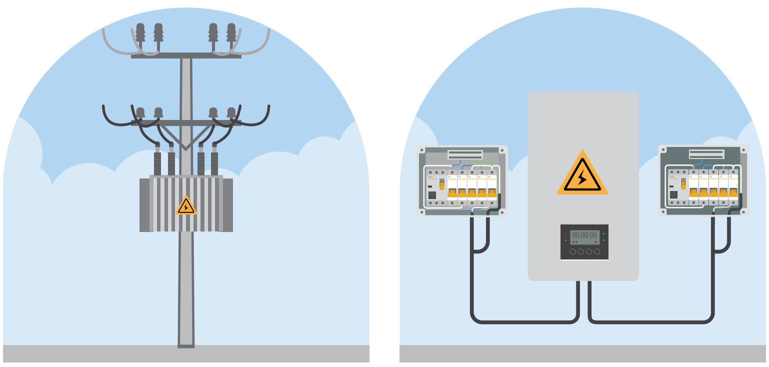
We have been replacing pillars based on inspection reports. However, given the continued ageing and safety risks of the failure mode we have developed a targeted program that looks to address the assets posing most risk.

The preferred option is the installation of a new pillar built to modern standards, with improved security of the enclosure. The targeted program will commence in 2025 and will be ongoing past 2030.

Non-targeted replacement volumes

In addition to our targeted program, our age-based modelling suggests that we will need to replace distribution substations (**Figure 41**) and switchgear (**Figure 42**) at slightly higher levels over the next 10 years. This is due to more assets reaching expected end of life, even accounting for the targeted programs.

Figure 40: Information on distribution substations



Asset Category	Darwin-Katherine	Alice Springs	Tennant Creek	Total
Distribution substations	4,160	561	136	4,857

Figure 41: Forecast volume of distribution substations (excluding targeted replacement)

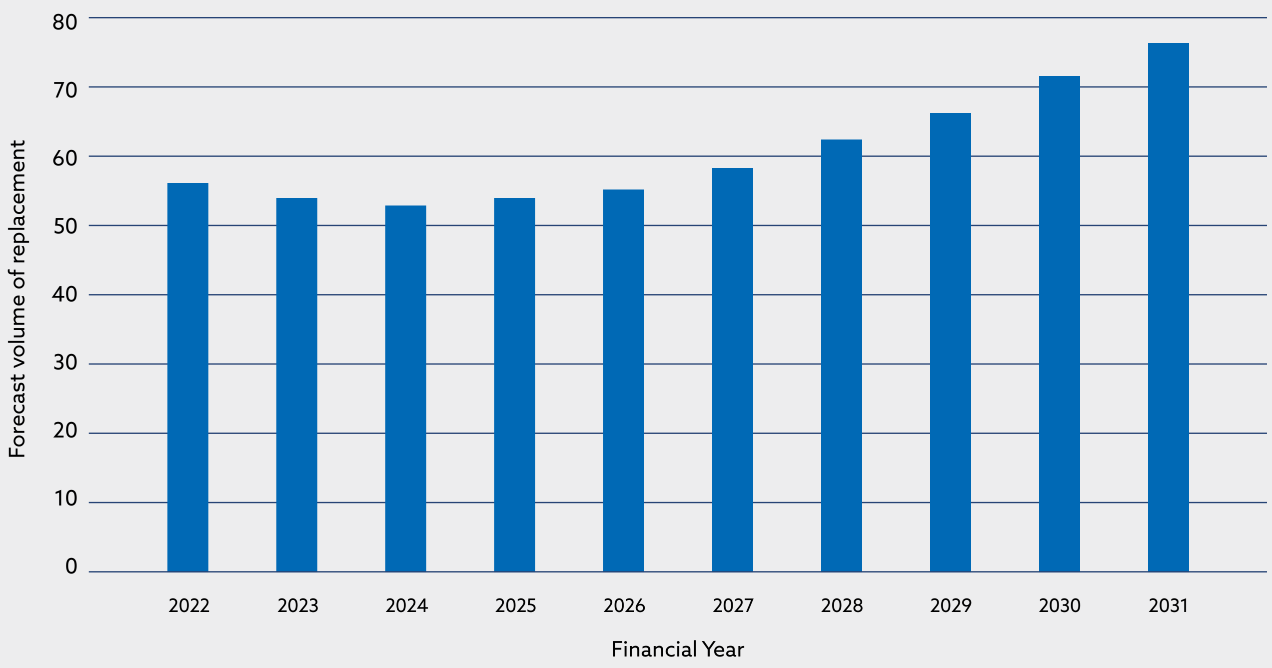
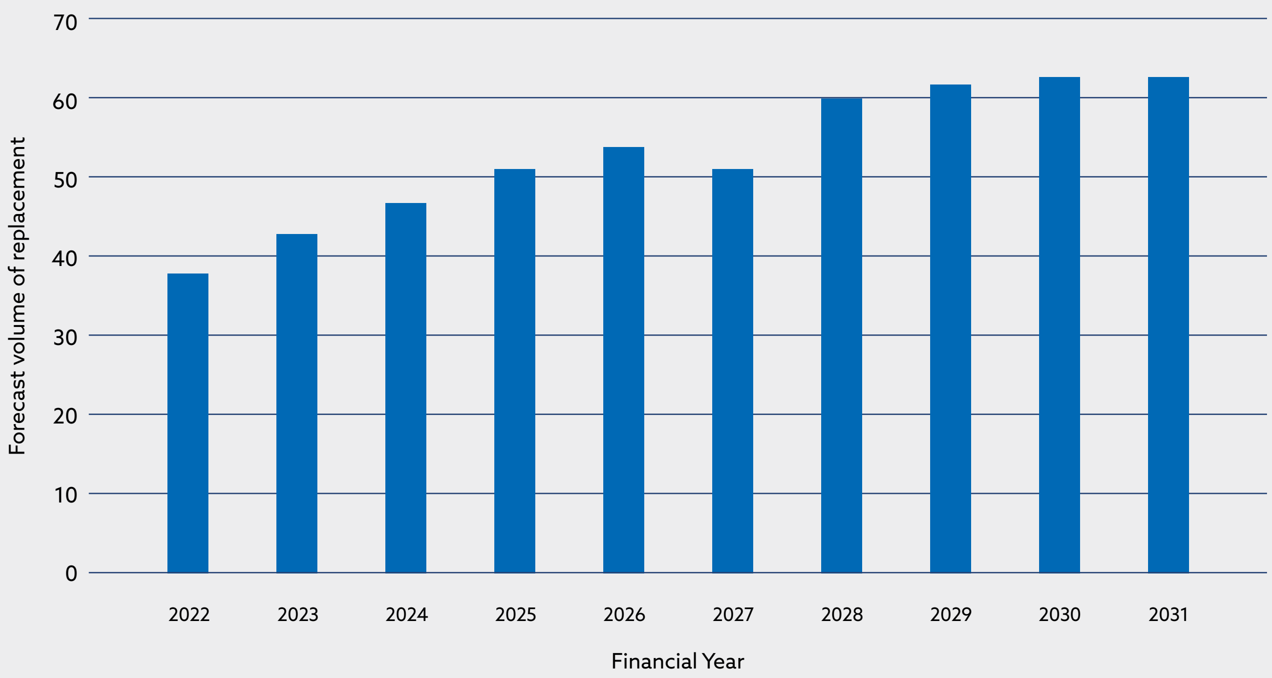


Figure 42: Forecast volume of distribution switchgear (excluding targeted replacement)



Power and Water engineers.

7.6 SCADA, communications and protection

The network requires control systems, communication networks and protection equipment to manage the network securely and safely.

SCADA is a control system that provides information and data on the network to system operators. Protection equipment detects faults and imbalances, ensuring the network remains within safe bounds. Communication assets are the key to transmitting information and data between assets and to operators.

These assets are becoming more critical in a network tasked with transporting a greater diversity, scale and location of generation. Further, in an age of cyber-security threats, it is critical that our communication assets are not compromised.

Below we have identified material targeted programs with a value of over $5 million. We have also identified minor programs.

We recognise that our plans for SCADA, communications and protection are not as advanced as other asset classes, and that more work needs to be undertaken on the need and options. We will bring this additional level of analysis to next year's TDAPR.

Obsolete communications technology ($14 million)

We are planning to replace SCADA and Communications assets that have reached the end of their serviceable life and are now using obsolete technology and are no longer supported by the vendor.

Vendor support is critical to having equipment repaired, resolving software and firmware bugs, updating security patches to guard against cyber threats, and general overall support in programming and maintaining this equipment. The project will be ongoing until post 2030.

Additional communication pathways ($9 million)

This is a new project that was not included in last year's TDAPR. To comply with our current technical code for communications, Power and Water is required to install additional communication pathways for SCADA. This provides back-up of data and information through a diversity of communication pathways. The program has already commenced and will continue past 2030.

Protection relays ($6 million)

This program was not included in last year's TDAPR as a targeted program. We will be progressively replacing electromechanical, static and first generation protection relays.

The key drivers of replacement include obsolete technology leading to a lack of spares and loss of vendor support, and lack of functionality to perform in a changing generation mix. The program has already commenced and will continue past 2030.

Darwin – Energy Management System ($13 million)

The Energy Management System (EMS) provides for a centralised control room including switching, outage management, contingencies, performance and dispatch. The system is at end of life, and is not suitable to manage the increasing mix of generation on the network. We will upgrade the EMS software to the current revision levels. The project has already commenced and is expected to be complete by 2024.

An additional component that was not included in last year's TDAPR are switches, routers, and security devices that are required for the operation of the EMS. We will likely need to replace these assets by 2029.

Minor programs

The additional minor targeted program is the battery replacement program. These provide backup supply for remote communication sites. We will report further on this program in next year's TDAPR.

8. Programs to address capacity, voltage and fault limitations

We expect to increase capital expenditure to upgrade the network over the next decade. The key drivers are pockets of peak demand growth from new commercial projects and housing developments, and increasing challenges with operating within safe voltage levels as rooftop solar installations rise. We also note that there are some large but very uncertain projects over the next decade that may require us to invest in new infrastructure.

In the following sections, we identify the capacity, voltage and fault limitations on transmission infrastructure, zone substations and distribution networks over the next decade.

Capacity limitations

We upgrade or build new infrastructure when our assets cannot securely meet peak demand in an area of the network.

With the stabilising of peak demand in recent years, the driver of capacity limitations relates to new commercial projects and housing developments. Over the next decade we expect significant growth in Palmerston, Humpty Doo and Katherine. This is driving new infrastructure needs predominantly on zone substations.

We note that there are five material, but very uncertain developments that may give rise to further network investment, and may impact the options assessment of other projects.

- The Northern Territory Government has outlined the need to build new transmission infrastructure to connect a renewable energy hub to the south of Darwin by 2025. We are working with the Northern Territory Government on our role in the project.
- There is the prospect of a substantial increase in energy demand at Humpty Doo in Darwin, which may require an even larger upgrade than planned to the zone substation, and additional transmission works.
- An industrial precinct at East Arm may require significant investment in a new zone substation.
- A new land development in Holtze and Kowandi, near Palmerston may lead to significant housing and commercial development in the area, which may result in the need for a new zone substation.
- A new development near Pine Creek may require significant voltage support of the 66kV transmission network.

These projects have been excluded from the next sections on the basis that there is uncertainty on the timing or role of Power and Water.

Voltage limitations

We also undertake augmentation works to meet the quality of supply criteria in our Network Planning Criteria.

Increasing rooftop solar over the next decade will pose voltage challenges in both the distribution and transmission networks. In this year's TDAPR we identify programs of work to address current issues with our transmission network and forecast voltage issues at the distribution network.

An area of uncertainty is the scope of works that will be required to meet the Northern Territory Government's implementation of an Essential System Services framework. It is likely that the new framework will place an obligation on Power and Water to procure services to meet new voltage and system strength standards. We will report back to stakeholders on this new framework in next year's TDAPR.

Fault limitations

We also address issues with assets operating above an equipment's fault level ratings. This often occurs because the network asset was initially built when the network had lower demand. When the network expands, the fault current can increase beyond the fault capacity of the existing assets.


Transmission lines, Wishart.

8.1 Transmission network

As part of our annual review, we have undertaken a review of the capacity of our transmission lines and sub-transmission substations in Darwin-Katherine and Alice Springs. All supporting technical data is set out in our data appendix accompanying this report.

At a high level, we are expecting to undertake minimal capacity upgrades of our transmission network. However, as discussed at the beginning of this chapter, there may be a need for transmission works relating to the new Renewable Energy Hub, and to meet demand at Humpty Doo.

There are two capacity constraints which will likely require investment over the next decade.

Darwin – Hudson Creek sub-transmission substation ($2 million)

Consistent with last year's report we have found that the Hudson Creek terminal substation is currently unable to supply connected substations in Darwin area if two of the three 125MVA transformers fail simultaneously.

Even with additional generation, the overloads are materially significant. Our preferred solution is to purchase a spare 132/66kV transformer, which will be used to replace a failed transformer.

Transmission lines ($3 million)

We have undertaken contingency analysis of our transmission lines to identify if any lines would exceed capacity in the planning horizon.

Under a critical contingency (N-1) on the line from Hudson Creek to Palmerston zone substation, the 66kV overhead line from Hudson Creek to Archer line is expected to exceed capacity by the end of the decade.

Similarly, under a critical contingency on the line from Hudson Creek to Archer zone substation, the 66kV overhead line from Hudson Creek to Palmerston line is expected to significantly exceed capacity by 2029-30.

The two options to address the overloads under N-1 include procuring additional generation at Weddell power station and uplifting the line ratings from 64MVA to 90MVA for each of the lines.

8.2 Zone substations

We forecast peak demand at each of our zone substations on an annual basis. This is used as an input to identifying capacity constraints over the 10 year planning horizon. The expected demand and overloads for zone substations is set out in our data appendix to this report.

We also identify where voltage rectification may be required at zone substations to meet our technical standards.

Below, we have identified key programs over the next decade, outlining our proposed network and non-network solutions. Additionally, we have identified other capacity limitations which can be addressed through load transfers.

Katherine zone substation upgrade ($20 million)

In last year's TDAPR, we noted an existing constraint at Katherine zone substation. We have provided new information on investment needs.

The Katherine zone substation comprises two power transformers of 20/33 MVA, and 20/27 MVA capacity respectively. The zone substation is already overloaded under a single critical contingency (N-1) of a transformer failure. In the short term, we are considering lower cost options to support load if one of the transformers fail such as batteries or an agreement to supply additional load from a local generator.

In the longer term, we see the need to upgrade the capacity of the zone substation as load continues to increase. Large housing developments and commercial loads are forecast to locate to the east of Katherine. This means that the load at risk will become significantly higher and a longer-term solution will be required.

At this stage, we consider the least cost feasible option to address the long term need will be to upgrade the existing zone substation commencing in 2025 and completed by 2026. However, we will continue to undertake more rigorous options analysis including assessment of non-network alternatives such as a local generation and batteries.

Humpty Doo zone substation ($10 million)

The zone substation has two 2.5 MVA power transformers that are connected by a 66kV radial line from Strangways.

The forecast load at 50 per cent POE is expected to exceed the firm capacity of the zone substation by 2028-29, mainly due to increased load requirements from connected and future committed customers in the area.

Currently, the limitation can be addressed through a load transfer to Strangways zone substation. We can install a spare Nomad (8/12 MVA) at Humpty Doo zone substation during emergency conditions.

We are currently assessing options on the optimal solution to concurrently address asset condition and capacity limitations. This includes examining whether the firm capacity at the zone substation should be increased at the time of replacement.

There is also potential for further significant demand in the Humpty Doo area. This may require upstream augmentation works including transmission line upgrades. We will continue to keep stakeholders updated on this project.

Demand management to support Wishart zone substation ($6 million)

As noted earlier in the chapter, we are expecting an increase in demand at East Arm from committed loads for a residential subdivision and Transport Industry Precinct, and future industrial loads in the East Arm and Wishart areas.

We currently have a modular substation at Wishart which can meet the current load under normal conditions but we expect load to increase.

At this stage, we consider non-network alternatives such as diesel generators could support the load in the short term. This would help us defer construction of a new zone substation that is expected in the future to supply committed and future loads.
We will continue to update our stakeholders on this development in next year's TDAPR.

We forecast peak demand at each of our zone substations on an annual basis.

Nomad substation, Wishart.

Archer zone substation ($1 million)

Archer zone substation currently consists of two power transformers of 20/27 MVA capacity. Under a single contingency (N-1) the zone substation cannot meet the expected demand forecast in 2021-22, mainly due to new housing developments in the area.

The system limitation can be addressed through a load transfer to Palmerston zone substation without a network or non-network solution until 2024-25.

We consider it would be prudent to install a nomad connection to connect the Nomad (8/12 MVA) at Archer zone substation if a single contingency occurs. This would ensure continued supply to customers at low cost.

Katherine zone substation – voltage rectification ($2 million)

As noted in section 4.2, we have operated outside of the safe low voltage range in Katherine for a significant period in 2020-21. To address this issue, we will be installing switched inductive compensation to lower voltage at the bus in the zone substation, which will have the impact of absorbing reactive power.

Capacity constraints not requiring investment

The following zone substations are likely to be overloaded over the planning horizon. However, our planning indicates that there are likely to be alternative options such as load transfers or transporting a spare transformer that mitigate the need for new investment.

- Weddell zone substation – This is located in Darwin and comprises three transformers with a combined N-1 rating of 15MVA. The forecast demand is exceeding the N-1 rating due to large industrial and commercial loads. The system limitation could be addressed through a load transfer to Strangways without a network or non-network solution.
- Cox Peninsula – The Centre Yard zone substation is located at Cox Peninsula which is serviced by an undersea cable from Darwin to Mandorah. We are forecasting that underlying load growth will continue to increase in the area. Under N-1, the zone substation does not meet the forecast load. However, we already have a generator with 1MW capacity in place in case of a contingency event.
- Batchelor and Manton – Both zone substations have significant capacity under normal operating conditions, but under N-1 cannot meet the relatively low load in the area. If a contingency were to arise at either zone substation, we can transfer the load to the other zone substation, that is, from Batchelor to Manton or Manton to Batchelor.
- Marrakai and Mary River zone substations – These are both single transformer zone substations at the far end of the Darwin rural network. Both substations have significant capacity to meet load under normal operating conditions, but under N-1 we would need to transport and connect a spare Nomad transformer with 8/12 MVA capacity to restore load in the area. We note that the substations have relatively young transformers so the risk of a failure is relatively low.
- Strangways zone substation – The substation services the Darwin rural area. It is comprised of two 20/27MVA power transformers and provides a 66kV radial line to Humpty Doo, Marrakai and Mary River zone substations. We are forecasting an overload under a single critical contingency (N-1). We consider the limitation can be mostly addressed by transferring load to Palmerston, Weddell and Manton zone substations. However, this may be impacted by uncertain developments in the area.
- Lovegrove zone substation – The 22 kV load connected at the zone substation cannot be met if the feeder 22LG29 (Jindalee) is out of service. While this is a relatively low load, we can supply the load with a spare 1 MW generator under emergency conditions.

8.3 Distribution and low voltage networks

In last year's report we reported on constraints on distribution feeders only. In the 2021 TDAPR we have identified additional investments to alleviate faults on distribution switchgear and identify the potential need to invest in improving voltage quality.

Distribution switchgear fault level program ($9 million)

This is an ongoing targeted program to replace switchgear with insufficient fault level capacity. Most assets are approaching end of life and are an old, non-standard configuration of HV switchgear that is known to be less safe to operate than modern equivalents. The program is expected to continue until 2029.

Reliability improvement program ($7 million)

In addition to capacity programs, we will also be implementing a reliability program for worst affected feeders as identified in section 4.1.

Based on recent trends, we consider that annual expenditure on this program would likely be $750,000 annually, as we incrementally improve performance in rural areas to meet our jurisdictional targets.

Distribution feeder capacity program ($7 million)

We have undertaken a 10 year forecast of demand at each of our distribution feeders to assess any capacity constraints.

We do not expect any material overloads across the distribution network, with only a handful of feeders overloaded in Darwin. The following zone substation areas will have a feeder that is forecast to exceed their capacity over the 10 year planning horizon:

- Archer (Darwin) – The Rosebury Hub (11AR15) feeder is forecast to be marginally overloaded in 2022-23 and will continue to increase.
- Palmerston (Darwin) – The Bakewell (11PA04) and Gateway (11PA26) feeders are both forecast to be overloaded by 2024-25.
- Berrimah (Darwin) – The Hidden Valley (11BE19) feeder is forecast to be overloaded by 2025-26.
- Leanyer (Darwin) – The Muirhead feeder (11LE12) is forecast to be marginally overloaded by 2029-30.

In all cases, the constraint can be addressed through load transfers to adjacent feeders in the zone. This means that we are expecting to undertake minimal investment in upgrading distribution feeders to 2030.

However, we note that based on historical trends, we undertake about $700,000 to augment the capacity and increase the flexibility of distribution feeders under emergency conditions.

Improving low voltage power quality ($10 million)

Based on historical trends, we currently spend about $1 million a year on increasing low voltage conductor size and upgrading distribution transformers to improve power quality.

As noted in section 3.1, a key long term planning focus area of Power and Water is to ensure we can securely and efficiently integrate more renewables into our network.

We are currently investigating options that would allow us to operate the network securely while allowing more solar to export energy. We will report back to customers on our Future Network Expenditure plans in the next TDAPR.

List of appendices

We have also published an accompanying Excel databook covering all technical data including asset population, maintenance strategies, and demand forecasts for our transmission network and zone substations. **Table 5** identifies the appendix number in each tab of the spreadsheet together with a description of the data and information.

Table 5: Items included in data appendix accompanying this report

Appendix Number	Description of data and information in the appendix
Appendix A	Asset count reported in 2020-21 Category Analysis RIN
Appendix B	Voltage regulation standards
Appendix C	Maintenance strategies
Appendix D	Transmission lines – demand forecasts and system limitations
Appendix E	Transmission contingency analysis
Appendix F	Zone substation – demand forecasts and system limitations
Appendix G	Distribution feeders – identified system limitations
Appendix H	Maps of the three regulated regions
Appendix I	System limitation template

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