Darwin-Katherine Electricity System Plan

Cleaner, more affordable and secure energy system by 2030



THE TERRITORY

NORTHERN TERRITORY GOVERNMENT

Acknowledgements

The Northern Territory Government respectfully acknowledges Aboriginal and Torres Strait Islander peoples as the First Nations people of this country.

We acknowledge the continuing connection to lands, waters and communities, and the evolving cultures of all our First Nations peoples.

We pay our deepest respects to all Aboriginal and Torres Strait Islander cultures, and to their leaders - past, present and emerging.

Minster's foreword

A cleaner power system for Darwin-Katherine

The Darwin-Katherine Electricity System Plan charts the pathway to achieving the Northern Territory Government's 2030 vision for renewables to supply 50% of energy consumed.

The Darwin-Katherine electricity system energises the homes of around 150,000 people in the region and is the backbone of our economy.

As the Northern Territory Government's 50% Renewable Energy Target by 2030 recognises, renewable technologies can offer clean, affordable and secure energy.

Over the last decade, we have seen a consistent increase in renewable technologies, not only across the Darwin-Katherine electricity system, but across Australia.

As our energy system continues to shift, it is critical that there is a comprehensive strategy to manage this change. The Darwin-Katherine Electricity System Plan (System Plan) provides this strategy.

The objective of the System Plan is to chart the pathway to 50% renewable energy by 2030 and guide policy, strategic and operational decisions to enable this.

The System Plan is designed to be nimble and dynamic. As technological advancements are realised, energy demand grows, or renewable technology costs decline, the System Plan can adapt to these changes.

The strategy is to address key challenges. These include ensuring there is enough electricity, maintaining a stable and secure network, whilst navigating a low cost and least regret pathway to guide investment decisions.

The System Plan is also tailored for our specific context – a stand-alone power system, which needs to recognise our limited renewables options and withstand our climate, including monsoons, humidity and cyclones.

Importantly, the System Plan aims to maximise opportunity for private investment, providing information on the nature and timing of these opportunities. In achieving the 50% Renewable Energy Target, generation and network costs in 2030 are projected to be less than today's costs.

The System Plan enables the Territory to advance low-emissions and diversified industrial growth to underpin the economic opportunities outlined by the Territory Economic Reconstruction Commission, including low-emissions advanced manufacturing, zero-emissions data centres and renewable hydrogen.

This builds on and complements existing investments in the Darwin-Katherine electricity system, including the Home and Business Battery Scheme, the Solar in Schools initiative, and the 35MW battery energy storage system.

It also recognises that more and more Territorians are investing in solar and battery technology for their homes and businesses and will continue to do so.

Energy systems are rapidly changing. This System Plan enables us to harness the opportunities of this change to deliver cleaner, affordable and secure energy to Territorians. We need to stay ahead of the curve – and this System Plan provides the pathway to achieve this.



The Honourable Eva Lawler MLA
Minister for Renewables and Energy

At a glance

A coordinated path forward

The Darwin-Katherine Electricity System Plan provides strategic guidance on a lower cost path to achieve the 50% Renewable Energy Target, recognising the vital coordination and leadership role the Northern Territory Government needs to play in guiding the electricity industry.

This strategic and overarching document will inform the operational decisions of the Power and Water Corporation, Territory Generation and Jacana Energy, ensuring coordinated and effective actions across government in an effort to realise a cleaner, lower cost and secure electricity system.

The System Plan identifies clear focus areas to achieve the renewable target, drawing on extensive analysis and expert advice. Figure 1 identifies the goals and key questions addressed in the System Plan.

10-year plan at a glance

The System Plan shows that abundant and low-cost solar in the region provides the perfect opportunity to replace ageing thermal generators. About 40% of the target can be met directly by solar generated during the day, including from rapid upscaling of large-scale solar complemented by continual growth in small-scale solar.

The analysis demonstrates the efficiency of locating large-scale solar in a Renewable Energy Hub close to the existing network, minimising connection costs and maximising the amount solar energy investors can provide. This will enable new opportunities for low-emissions industrial growth, in alignment with the Territory Economic Reconstruction Commission recommendations.

Batteries will store solar energy during the day and discharge at night. The System Plan targets about 10% of the Renewable Energy Target being met by storage batteries, most of which is expected to be connected to large-scale solar, but with home and community batteries playing a supporting role.

The System Plan identifies an ongoing need for new thermal generation to replace some retiring generation plants. The new thermal generation will be different from today – smaller, faster, and compatible with emerging new renewable technologies, such as hydrogen.

The System Plan also identifies that 'high spec' batteries will be vital to secure the network. Our analysis shows these batteries will play a vital role in efficiently providing many essential system services previously provided by heavy thermal machines.

The System Plan highlights the potential for emerging technologies such as Virtual Power Plants (VPPs) to efficiently coordinate the solar, batteries and customer appliances, such as electric vehicles.

The System Plan also shows how demand management initiatives that encourage customers to use energy during the day, when solar generation is at its peak, can unlock further benefits. Encouraging charging of electric vehicles during daylight hours will be a key initiative.

The System Plan analysis demonstrates that the proposed investments will lead to a cleaner, more affordable and secure system.

Future proofing beyond 2030

While the planning horizon is focused on 2030, the System Plan recognises the target of net-zero emissions by 2050. It also recognises that demand growth not foreseen today could be triggered by low-emissions economic growth in a vastly expanded local economy.

The central challenge is how to progressively retire heavy thermal generation while keeping the system secure. The 10-year plan looks largely towards batteries as the long-term solution to keep the system secure for a full transition to renewables.

We also want to ensure that any new technology provides clean energy in the future. For this reason, we set out a plan for new thermal generation to be compatible with renewable hydrogen in anticipation of this fuel source becoming viable.

Consultation

The System Plan is the start of a continuing longer conversation with stakeholders on the optimal development of the power system.

The System Plan recognises the fast pace of change in the renewables sector and will be updated biennially to integrate new knowledge, changes to underlying demand assumptions and progress against the 50% Renewable Energy Target.

The System Plan shows that solar and batteries are the key to achieving the 50% Renewable Energy Target securely by 2030, at low cost.

Figure 1: The 50% Renewable Energy Target



THE KEY QUESTIONS

What is the best mix of renewable technology?

What role will batteries play to store renewable energy?

What network investments to transport the renewables?

What technologies can help secure the network?

WHAT

HOW

How do we best coordinate large-scale renewable generation?

How do we best coordinate small-scale renewable generation?

How do we plan for an increase in low-emissions industrial growth'?

When is the best time to connect renewable generation?

When do we introduce battery storage?

When do we need to secure the network?

WHEN

WHERE

Where do we locate renewable generation?

Where is the best place to locate batteries?

Where do we build new power networks?

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Summary



Image supplied: Power and Water Corporation

The Northern Territory is in the ideal position to realise a cleaner, lower cost and secure electricity system by 2030. On our doorstep lies a low cost and abundant resource – the sun – that can support the transition to a low-cost low-emissions electricity system.

We are also seeing advancements in battery technology that can secure the system and store energy for use when the sun is not shining.

In 2017, the Northern Territory Government set out a roadmap to meet a 50% renewable electricity system by 2030.[1]

The Roadmap to Renewables articulated the global and domestic context for decarbonising the electricity system. This included the need to safeguard the Territory from the adverse impacts of climate change, such as extreme rain, extreme heat and sea level rise.

Greenhouse gas emissions from the Northern Territory's electricity sector in 2018 were approximately 14% of its total emissions[2]. Reaching the 50% Renewable Energy Target by 2030 will significantly contribute to lowering emissions in the electricity sector and, therefore, total emissions.

The Roadmap to Renewables also identified the technology opportunities to achieve a low-cost transition to secure a 50% Renewable Energy Target.

This System Plan is the roadmap for the Northern Territory's transition to 50% renewables, and presents the government's findings and views to guide policy, strategy and operational decisions.

The possibilities and challenges

The Northern Territory is in a prime position to deliver cleaner and more affordable energy services by 2030.

The Darwin-Katherine electricity system has unique features that will enable the transition to the 50% Renewable Energy Target, including:

- access to abundant solar, providing a low-cost opportunity compared to current thermal generation
- small industry size providing the ability to coordinate across government and industry quickly and directly with an integrated approach to risk management
- significant experience in the operation and management of small power systems with unique challenges
- extensive micro-grid experience necessary to guide development of the Darwin-Katherine electricity system.

There are always challenges with disruption and transition. In implementing paradigm changes, we are resetting a long history of power system development, including in the Darwin-Katherine region.

Each jurisdiction in Australia is managing the transition to renewable energy. The three key challenges with transitioning to delivering a 50% Renewable Energy Target by 2030 are:

- ensuring the new generation mix meets customer demand and expectations
- keeping the system secure under all conditions
- keeping costs as low as practical.

This System Plan is solutions-orientated. The pathway to 50% renewable energy by 2030 is based on knowledge of today and expectations of technology advancement in the medium to longer term. The pathway may change as new information and analysis arise in the future and this will be reflected in a refreshed System Plan every two years. Chapter 1 of the System Plan provides further context to the development of this Plan.

Analysis and scenarios

What will the Darwin-Katherine electricity system look like in 2030 and beyond? There are many unknowns with forecasting, particularly as we emerge from the COVID-19 pandemic. These include how customers use energy, uptake of rooftop solar and home batteries, and changes to industrial demand.

The System Plan considers three plausible scenarios for the Darwin-Katherine electricity system in 2030 (see Figure 2). The scenarios help identify the investments required to reach the 50% target under varying circumstances.

The "From Little Things" scenario is based on modest demand growth and assumes that the 50% Renewable Energy Target is met mostly from small scale renewables.

The 'Seek Different' scenario has higher demand growth and assumes that large-scale renewables lead the delivery of the 50% Renewable Energy Target. This scenario aligns with demand projections articulated in the Utilities Commission's 2020 NT Electricity Outlook Report.[3]

The 'Sunshine for Sale' scenario is based on a step-increase in demand, met predominantly by large-scale solar capacity. This scenario aligns with the government's vision for a $40 billion economy by 2030[4].

The analysis supporting the System Plan focuses primarily on the 'Seek Different' scenario to guide analysis of key challenges and focus areas. The alternative scenarios have aided understanding of how proposed solutions or investment timing may change as the future unfolds.

A range of external experts and local industry has informed understanding of technology, system limits, and emerging innovations. Chapter 2 of this System Plan outlines the analysis undertaken in more detail and outlines assumptions used for each of the three scenarios.

Figure 2: Key scenarios of the Darwin-Katherine electricity system



From Little Things

Modest growth in demand for elecricity from custom

The 50% Renewable Energy Target is mostly met by growth in small-scale solar, including rooftop solar, anc storage from home and community batteries



Seek Different

Faster pace growth in demand for electricity from customers

Most of the 50% Renewable Energy Target is met by large-scale solar and large storage batteries



Sunshine for Sale

Booming demand for electricity from customers

Large-scale solar and mass storage required to meet t. 50% Renewable Energy Target



A key feature of the System Plan is a Renewable Energy Hub to centralise and coordinate investment.

The Renewable Energy Hub can connect to available capacity on transmission lines close to Darwin, minimising connection costs and maximising renewable generation.

Focus areas

The System Plan identifies six focus areas that collectively support 50% renewable energy by 2030 securely and at lower cost. The focus areas address the key questions – what, where, when and how the target will be achieved to deliver a cleaner, lower cost and secure system.

While the modelling in the System Plan provides precise estimates, our pathway sets out approximate values recognising that end needs are likely to vary with circumstances.

Figure 3 sets out the key focus areas identified in the System Plan under the Seek Different scenario with a summary provided below. Chapter 3 discusses the focus areas in more detail.

Solar

Under all scenarios, the need to install solar as the primary renewable source to achieve the 50% Renewable Energy Target is clear. This will require investment in large-scale-solar in a shared location (what is termed a 'Renewable Energy Hub') close to existing transmission lines to significantly reduce costs and maximise generation output. More small-scale solar (also termed 'behind-the-meter') will complement large-scale solar.

Storage batteries

Batteries are needed to store surplus solar during the day to be used during the evening and night. Batteries will be located primarily next to large-scale renewable generators but will be complemented by home and community batteries.

New agile thermal generation

Targeted investment in small, agile and hydrogen-ready thermal generation will be required to ensure secure energy when the sun is not shining. These machines will be small, reflecting the need for flexibility and more limited operations. The machines will also be compatible with renewable hydrogen in readiness for when this resource becomes viable.

High spec security batteries

High spec security batteries will be essential to assist to secure the network, as solar replaces thermal generation. The System Plan draws on analysis that shows how high spec batteries securely and efficiently provide essential system services (ESS) currently provided by thermal machines, including frequency control services.

Virtual Power Plants

The System Plan recognises that emerging technologies, such as VPPs, will be vital for aggregating and coordinating small-scale renewables and emerging technology.

Demand management initiatives

The plan also recommends demand management initiatives to encourage customers to be more conscious of energy consumption, including shifting demand from the evening to the day when low-cost solar can be activated.

Figure 3: Key focus area – 'Seek Different'

320 MW NEW

Focus area 1

Solar and Renewable Ener

- Small-scale solar (80MW)
- Committed large-scale solar (60MW)
- Large-scale solar in Renewable Energy Hub (180.

110 MW NEW

Focus area 2

Storage batteries

- Home and community storage (10MW/40MWh)
- Large-scale storage (100MW/560Mwh)

200 MW RETIRE
80 MW NEW

Focus area 3

Thermal generation

- Retire ageing thermal generation (200MW)
- Install smaller, faster, hydrogen-capable mach. (80MW)

105 MW NEW

Focus area 4

High spec security batteries

- Install three new high spec batteries (105MW)

NEW

Focus area 5

Virtual Power Plants (VPPs)

- Operate and expand a VPP

NEW

Focus area 6

Demand management initiatives

- Encourage customers to shift energy use from evening to during the day

Bringing it together – sequencing focus areas

The System Plan identifies the sequencing of the six focus areas, based on three key stages. Timing is crucial. Careful planning is required to ensure investment is efficient and delivery capability is available. There are 3 key stages.

Ready (2021-23)
This stage is about building the foundations and addressing the current transitional challenges of the electricity system. The most significant work is to plan, resource and construct a Renewable Energy Hub for large-scale solar. This stage involves executing committed projects, including 60MW of large-scale solar on the Darwin-Katherine Transmission Line (DKTL). The first of 3 high spec batteries to secure the system will be proven in 2023. This stage is also about getting ready for new platforms, such as VPPs, to better coordinate small-scale solar.

Set (2024-26)
This period involves early investment in new large-scale solar, ahead of the expected retirement of gas generators from 2027, and bringing forward investment in a second high spec battery to maximise generation from existing large-scale solar. This battery will also play a crucial role in providing security in Stage 3. Storage batteries and VPPs will be operated but at low scale.

Go (2027-30)
This is the pivotal transitional period when existing thermal generation is retired and replaced with solar complemented by battery storage. New agile thermal generation will be progressively added to the generation mix to meet overnight demand. A third high spec battery will be required to keep pace with the security needs of the power system.

Figure 4 shows the expected progress to the 50% Renewable Energy Target based on System Plan modelling. Figure 5 sets out the key activities in each stage. Chapter 4 provides more detail on the drivers , sequencing and timing of each element of the System Plan.

Figure 4: Journey to meet the 50% renewable target

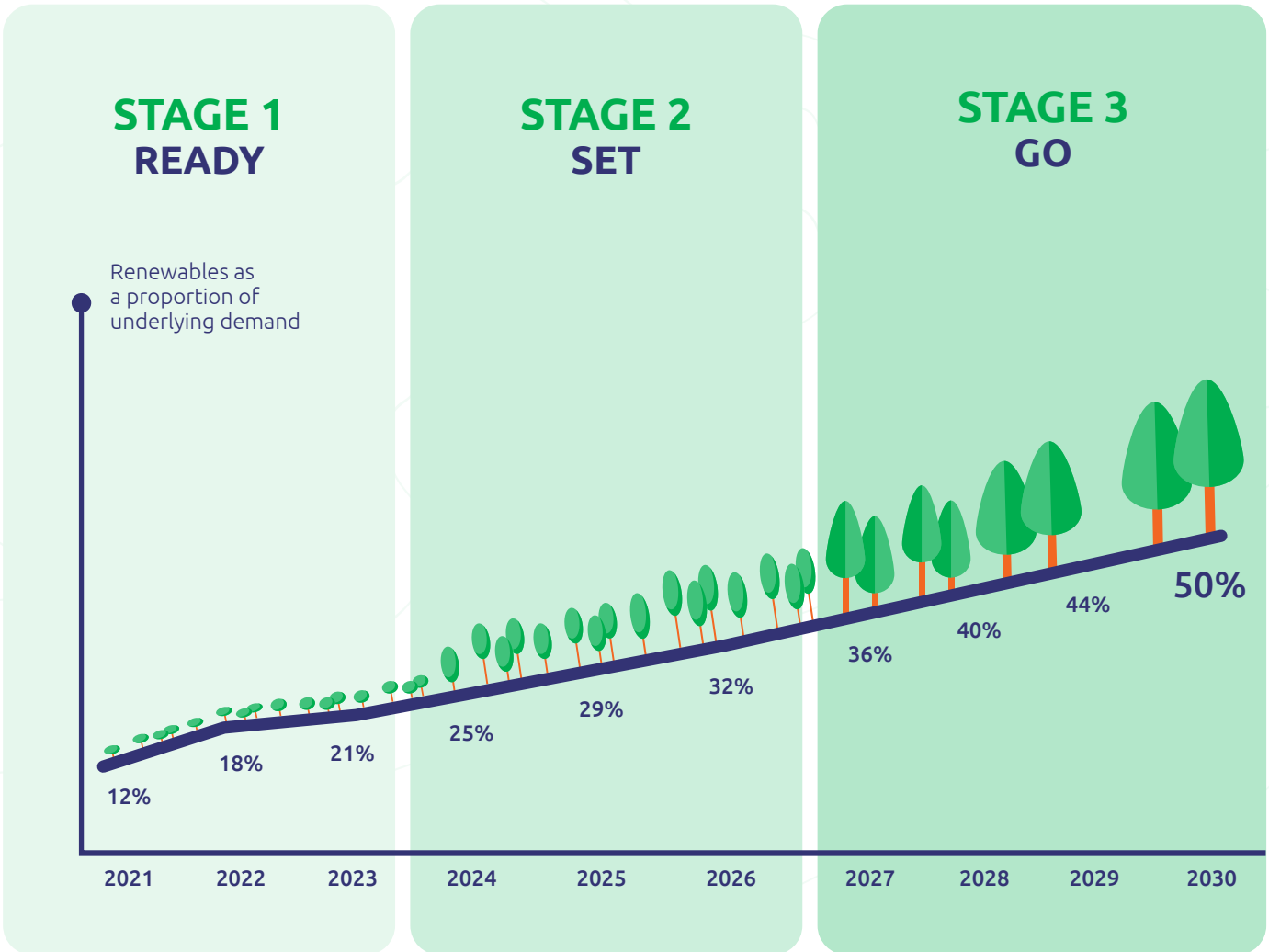
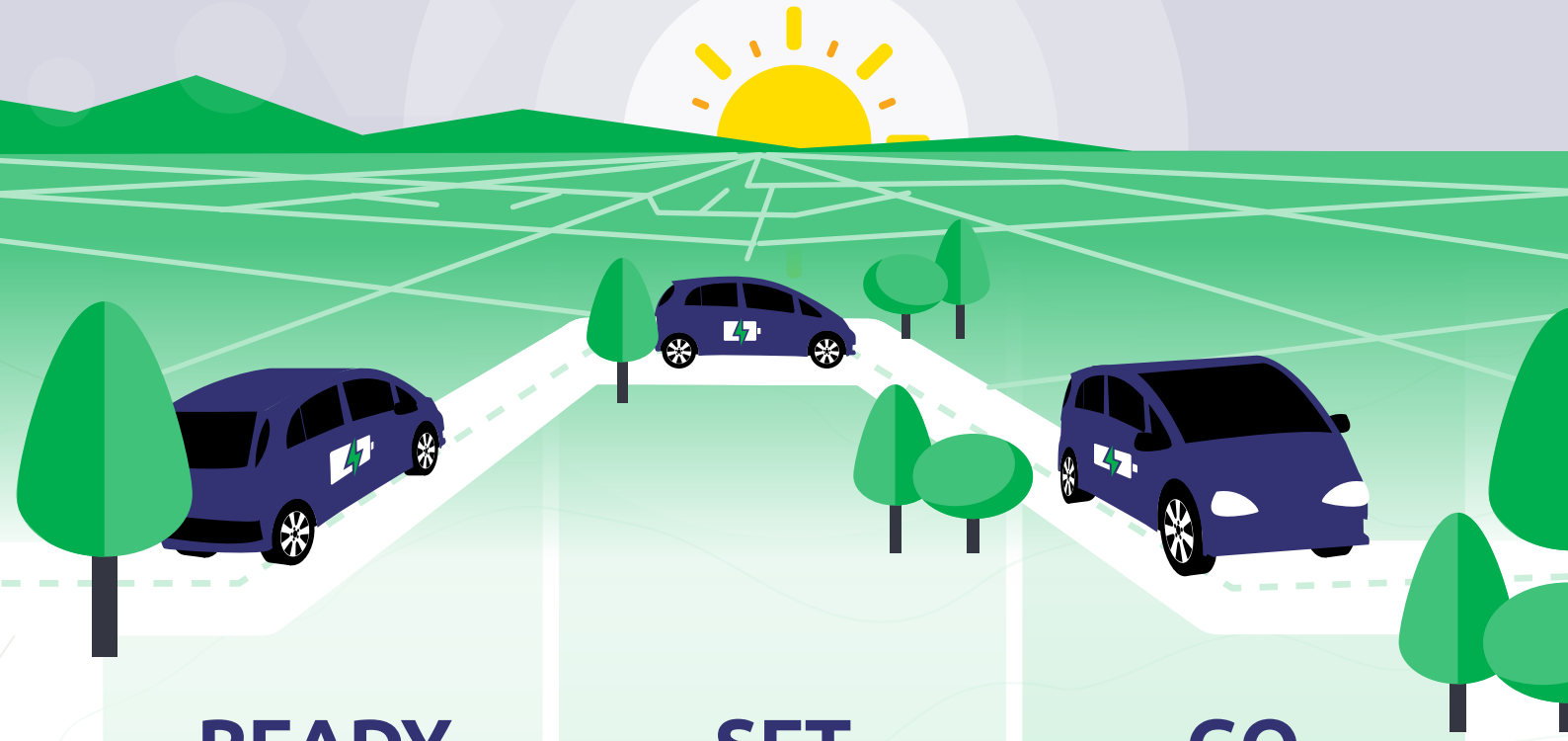


Figure 5: Sequencing of focus areas over 10 years



READY
2021-23

- Plan and construct Renewable Energy Hub
- Operate first high spec battery to provide system security
- Connect committed large-scale solar

SET
2024-26

- Connect initial solar farms to Renewable Energy Hub
- Operate second hight spec battery to maximise solar generation
- Establish VPP at limited scale

GO
2027-30

- Connect more solar to Renewable Energy Hub, and large storage batteries
- Operate third security battery
- Retire thermal machines, with ‘slimlined’ machines

Sequencing activities is the key to achieving the outcomes. Timing is crucial - careful planning is required to ensure investment is efficient, and capabilities and consequences of potential delays are recognised.

Outcomes and benefits

Meeting the 50% target

Figure 6 charts the expected change in generation mix between 2021 and 2030 necessary to achieve the 50% Renewable Energy Target. In 2021, thermal generation is expected to account for 88% of underlying energy, with 9% from small-scale solar and 3% from large-scale solar.

Under the Seek Different scenario of the System Plan, by 2030, 50% of underlying energy will be met by renewables, consisting of 15% small-scale solar and 26% large-scale solar, with 9% from utilising battery storage. The remaining 50% of electricity generation will come from more efficient and agile thermal energy, including a new plant that is compatible and ready for a hydrogen future.

Figure 7 shows how the generation mix may be sent out each hour on a typical day in 2030 under the central scenario. It shows that during the day, energy would be delivered by large-scale solar and, to a lesser degree, small-scale solar. A small proportion of energy would be met through thermal generation to ensure the security of the system, complemented by 3 high spec security batteries. Surplus solar production during the day would be stored in batteries and discharged overnight. Thermal generation could run evenly overnight, improving the efficiency and costs of providing electricity generation.

Addressing network security

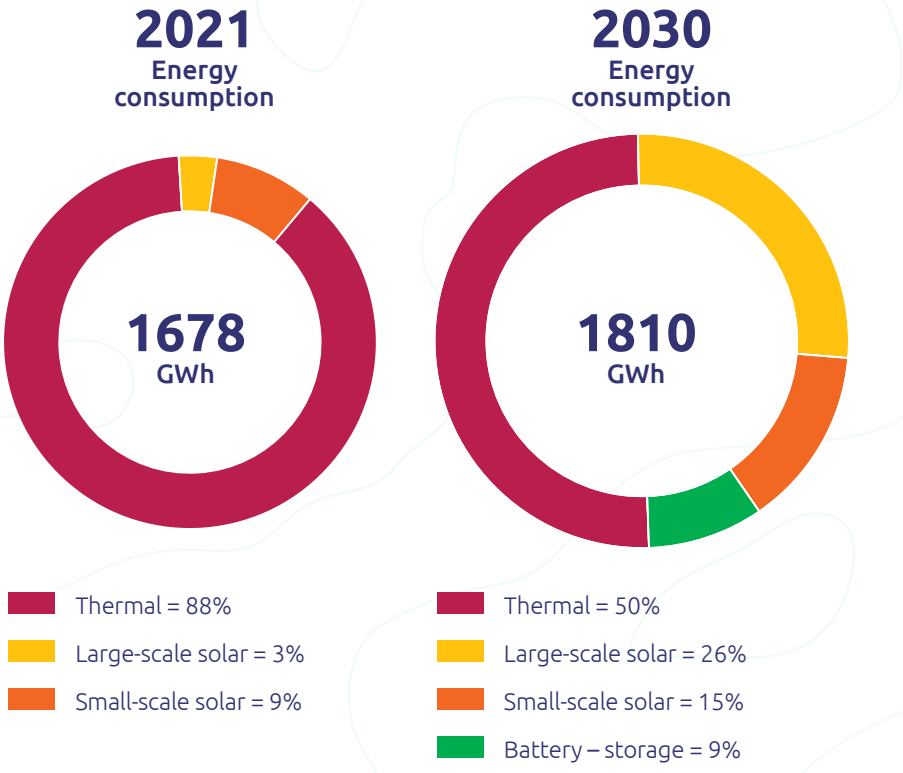
System Plan modelling tested the robustness of the generation mix to meet power security needs under extreme challenges. The modelling demonstrated that the generation mix in 2030 would continue to supply demand in the evening peak period, even with a major generator out of operation. The modelling also showed that electricity supply remains unaffected on continuous days of monsoonal weather where solar is limited, as there is sufficient thermal and battery generation, even with a major generator out of operation.

Power system security was also tested, including minimum demand days when energy required from the system is very low. The three high spec batteries were able to secure the system with limited thermal generation. These batteries have the added benefit of being able to expand the operating and technical envelope of the power system.

Cost savings of meeting 50% Renewable Energy Target

The System Plan found that achieving the 50% Renewable Energy Target resulted in an approximate cost saving of $30 million per annum, compared to following a Business As Usual scenario where retiring generation is replaced with similar equivalent technology (see Figure 8). This estimate does not factor in further cost savings that may be achieved from demand management or other efficiency savings.

Figure 6 - Change in generation mix by 2030



50%

of underlying demand by 2030

Currently 12% of underlying demand is met by renewables. Under the System Plan, we show that small and large-scale solar, together with battery storage, will deliver **50% of underlying demand by 2030.**

Figure 7: Generation each hour on a typical day in 2030

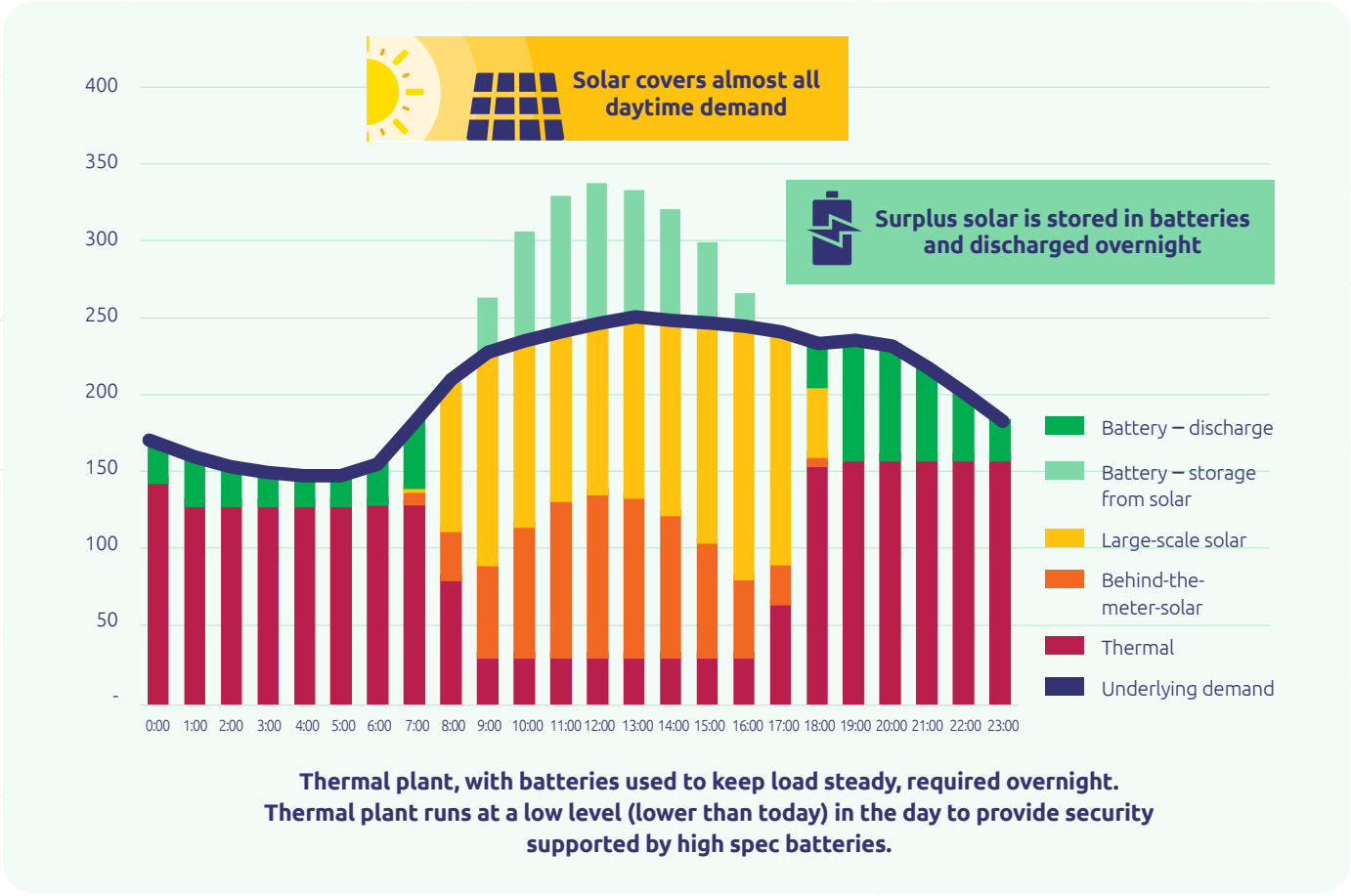
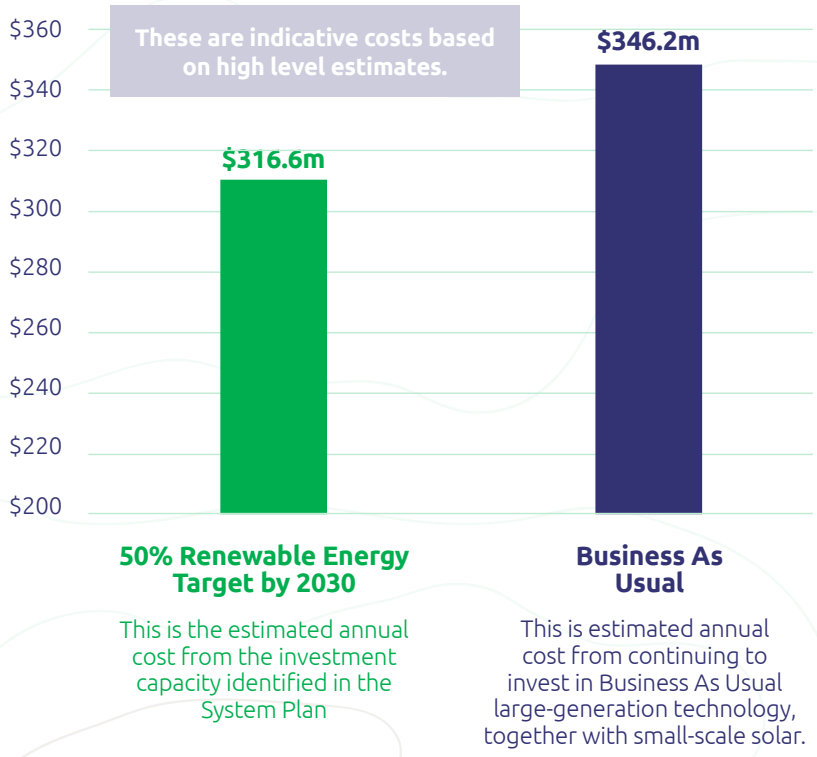


Figure 8: Annual (net present value) costs of generation and network by 2030 (2020 real dollars - million)



Lower emission benefits

As would be expected, the modelling in the System Plan shows that the 50% Renewable Energy Target results in significant emissions reductions in the electricity sector for each unit of energy (MWh) supplied. Figure 9 shows that emissions per MWh fall significantly, compared to the Business As Usual case.

These emissions reduction benefits have not been expressly quantified in the System Plan and are consequently expected to further increase the benefits of the 50% target.

Demonstrating the government's green credentials by being an active contributor to a global emissions reduction response will deliver valuable economic benefits, given emerging international policy stances that serve to impose a tax, whether direct or indirect, on carbon.

Figure 9: Annual emissions intensity from electricity demand (tonnes CO_2-e/ MWh)

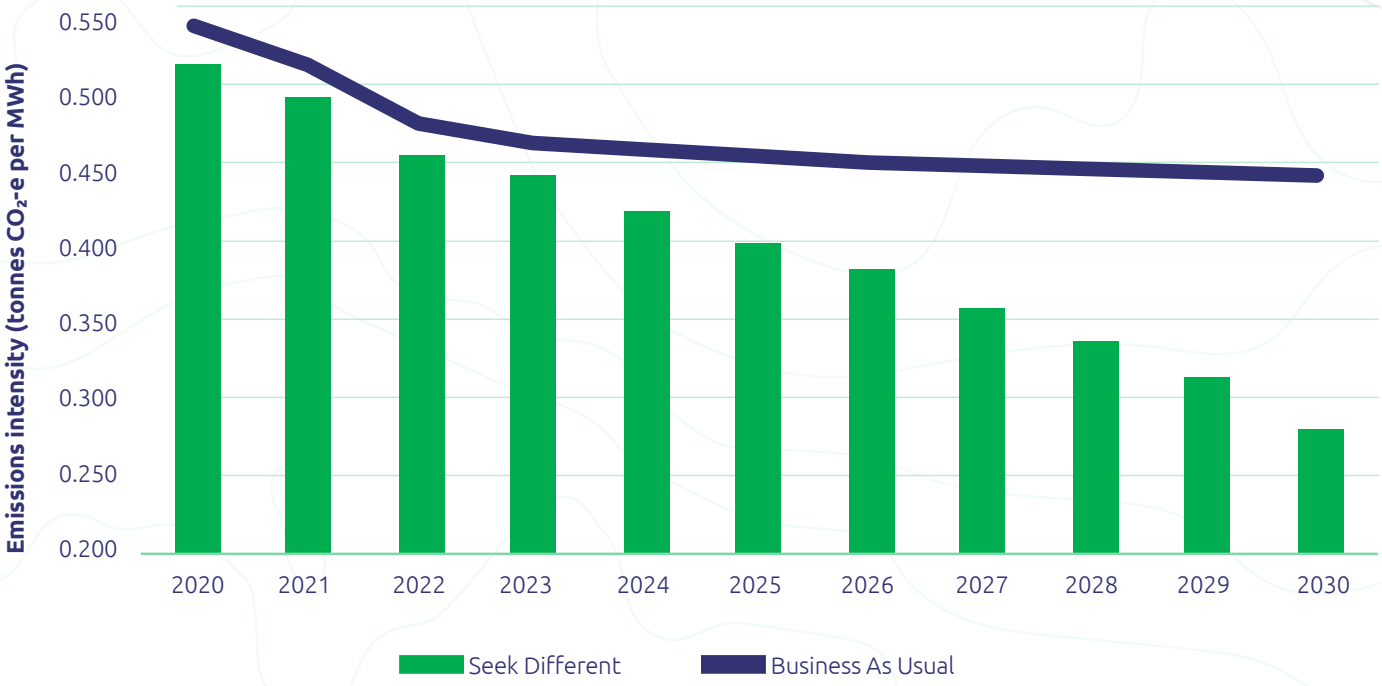




Figure 10: A dynamic roadmap for the Darwin-Katherine Electricity System Plan



Target by 2030

320 MW NEW

Focus area 1
Solar and Renewable Energy Hub

- Small-scale solar (80MW)
- Committed large-scale solar (60MW)
- Large-scale solar in Renewable Energy Hub (180MW)

110 MW NEW

Focus area 2
Storage batteries

- Home and community storage (10MW/40MWh)
- Large-scale storage (100MW/560Mwh)

200 MW RETIRE
80 MW NEW

Focus area 3
Thermal generation

- Retire ageing thermal generation (200MW)
- Install smaller, faster, hydrogen-capable machines (80MW)

105 MW NEW

Focus area 4
High spec security batteries

- Install 3 new high spec batteries (105MW)

NEW

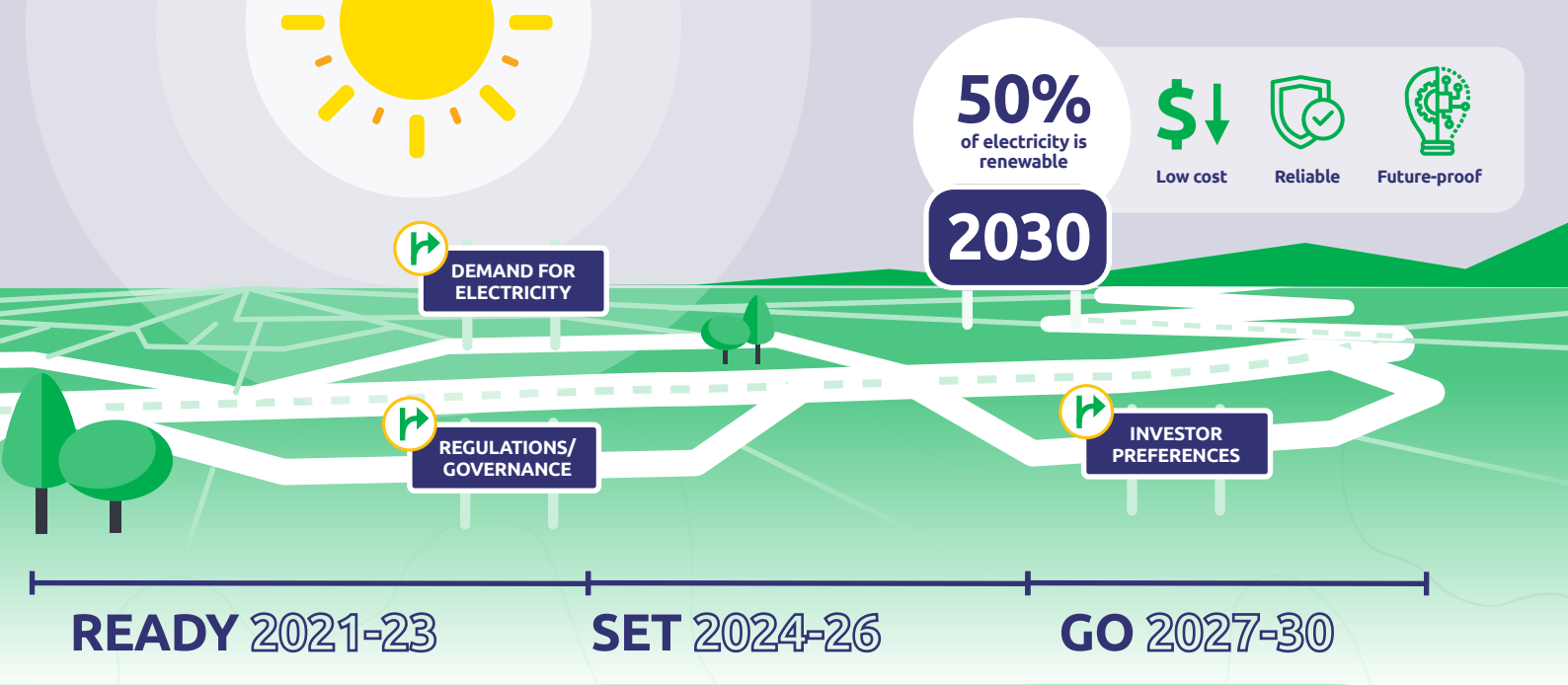
Focus area 5
Virtual Power Plants (VPPs)

- Operate and expand VPPs

NEW

Focus area 6
Demand management initiatives

- Encourage customers to shift energy use from evening to during the day



READY 2021-23	SET 2024-26	GO 2027-30
Connect 25MW of behind-the-meter-solar (2021-23)	Expected 25MW of behind-the-meter solar (2024-26)	Plan for 30MW of behind-the-meter-solar (2027-30)
Connect 60MW of committed solar to DKTL (2021-23)	Improve dispatchability on DKTL (2024)	
Construct Renewable Energy Hub and transmission assets (2021-24)	Target 60MW+ connection in Renewable Energy Hub (2025-26)	Target 120MW connection in Renewable Energy Hub (2027-30)
Install 2MW of home and community batteries (2021-23)	Install 3MW of home and community batteries (2024-26)	Install 4MW of home and community batteries (2027-30)
		Install 100MW of large-scale storage batteries (2027-30)
		Retire 9 thermal generation at end of life (2027-30)
Design specification of new agile thermal generation	Preparatory work for new agile thermal generation (2024-26)	Install four new 20MW thermal generators (2027-30)
Manage minimum demand until first new battery system (2021-22)	Successful demonstration of first battery's performance	Install and operate third large battery system of 35MW (2028)
Install and operate first large battery system of 35MW (2021-2023)	Install and operate second large battery system of 35MW (2024)	
Get VPP ready - identify options, and develop business cases (2022-23)	Use limited VPP services on solar and batteries (2024-26)	Expand VPPs to accommodate broader set of devices (2027-30)
Consider pricing initiatives to encourage energy usage during the day (2023)	Consider pricing initiatives to encourage energy usage during the day (2024-26)	Initiatives to encourage electric vehicle charging during the day (2027-30)

1. Context



Image supplied: Power and Water Corporation

The Darwin-Katherine electricity system is poised for transformation, with a rare opportunity to pivot to a lower cost, cleaner and secure energy system.

The Darwin-Katherine Electricity System Plan charts the Northern Territory Government's path to achieving a 50% Renewable Energy Target by 2030.

1.1. Darwin-Katherine electricity system

The Darwin-Katherine electricity system (see Figure 10) provides electricity to 150,000 Territorians[5] and across a diverse range of small, medium, and industrial-scale businesses.

In 2021, about 88% of energy is expected to be met by thermal generation. The generators connect to the electricity network, which conveys the electricity to households and businesses. In 2021, approximately 9% of underlying energy will be supplied by small-scale solar generation, and 3% by large-scale solar generation.

The Darwin-Katherine electricity eystem is unique and different from power systems in other parts of Australia.

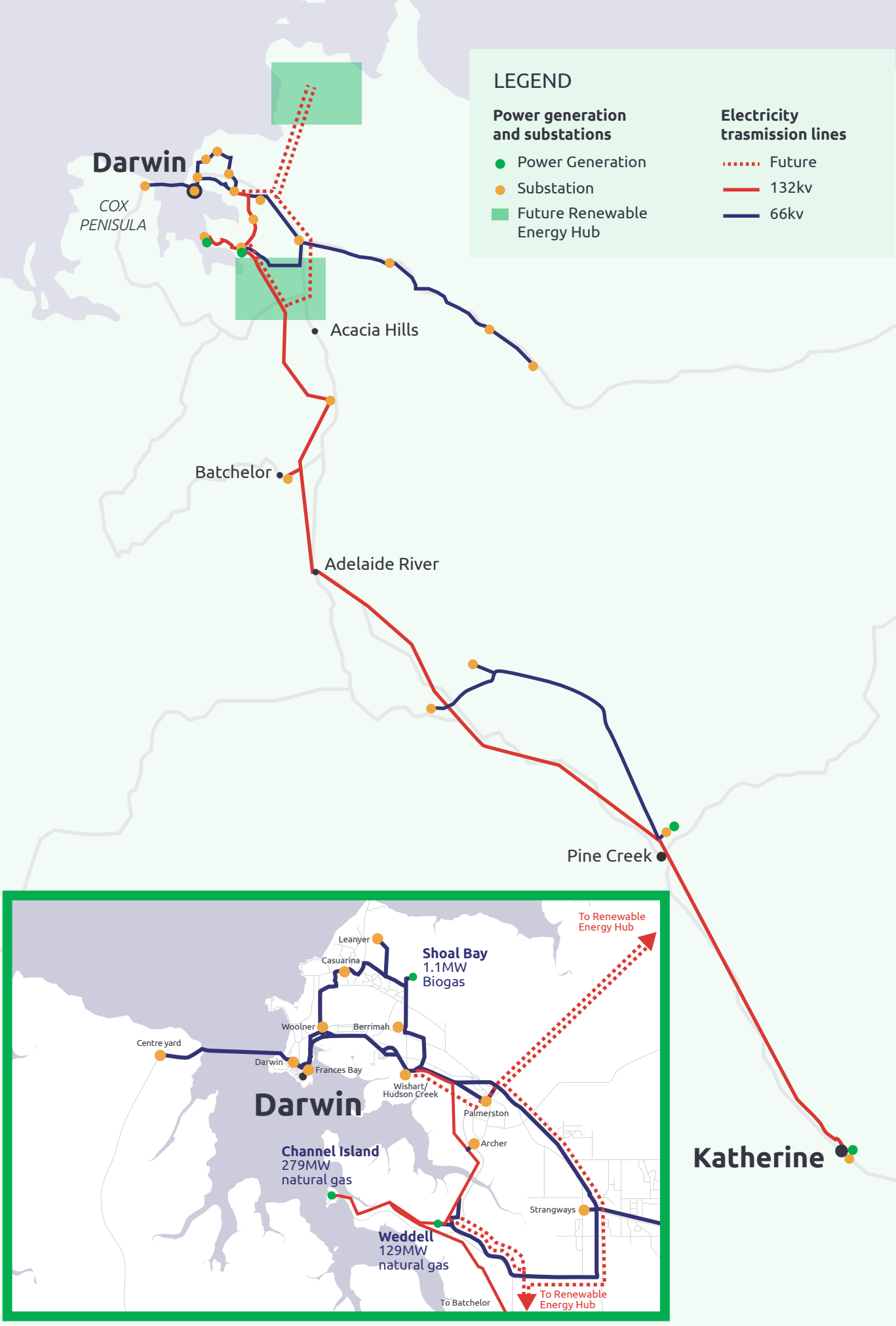
- It is a small standalone grid, delivering the equivalent of only 1% of total energy generated in the National Electricity Market. Economies of scale are difficult to achieve.
- Due to geographic remoteness, the Darwin-Katherine electricity system is not interconnected with other regional networks, such as Alice Springs or Tennant Creek, therefore fit-for-purpose, bespoke solutions are necessary.
- The operating environment is harsh and subject to weather volatility, particularly cyclones and monsoonal periods when the sun does not shine. Demand needs to be met despite the extreme weather, which can potentially also affect system security.
- Significant natural resource opportunities exist, including low-cost solar. However, there are current limitations with viably accessing alternative renewables (such as the wind, tidal, hydro, hydrogen and biofuels).
- There has been significant reform to the electricity market over the last decade, including structural separation of generation, networks and retail, and regulatory reform.

The System Plan has carefully considered, and recognises, the need for the Territory Government's broader policy and strategic agenda to work in parallel, including:

- the Territory Economic Reconstruction Commission's final report – That sets out an ambitious goal of a $40 billion economy by 2030, leading to more jobs and higher living standards for all Territorians[6]. The vision aligns with the 'Sunshine for Sale' scenario
- initiatives to promote renewable technology uptake, such as the Home and Business Battery Scheme[7] and Solar in Schools[8] programs.
- electricity market reforms, such as for Essential System Services and wholesale market changes[9].

The System Plan acknowledges that continuing reform will impact the deliverability of the six focus areas, and ensures that strategic policies and actions are complementary. For example, the prospect of a new Essential System Services market provides financial opportunities for batteries to provide efficient security services.

Figure11: Map of the Darwin-Katherine electricity system



1.2. A changing energy system

In the Darwin-Katherine Electricity System, one in six customers has solar panels[10], accounting for almost 80MW of installed capacity in the power system. This has resulted in three key changes to the way the power system operates.

- Customers are using more of their own solar generation to power their homes and businesses during the day, rather than using energy from the system. Homeowners and businesses are being encouraged to install battery storage to maximise the benefits from rooftop solar generation.
- Customers are exporting their solar into the grid, meaning less need for centralised generation from the power network during the day.
- Energy-efficiency appliances and new housing, together with demand management, are having an impact on the amount and timing of customers' underlying demand.

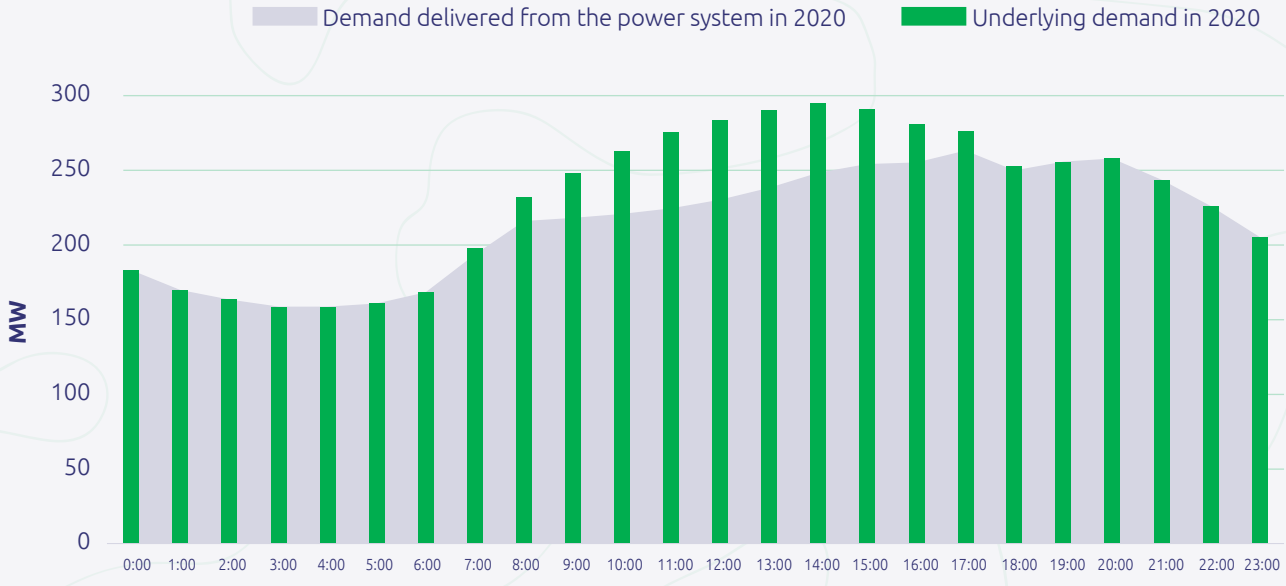
In the Darwin-Katherine electricity system, underlying demand has traditionally peaked in the late afternoon, particularly in the wet season when airconditioners are used to deal with the heat and humidity.

However, solar uptake has altered demand patterns. By using low-cost solar, demand growth in the middle of the day has been flattened, deferring the need to build expensive new generation and network assets. This is illustrated in Figure 12, which compares what maximum demand from the system would have been in 2020 if small-scale solar had not been installed.

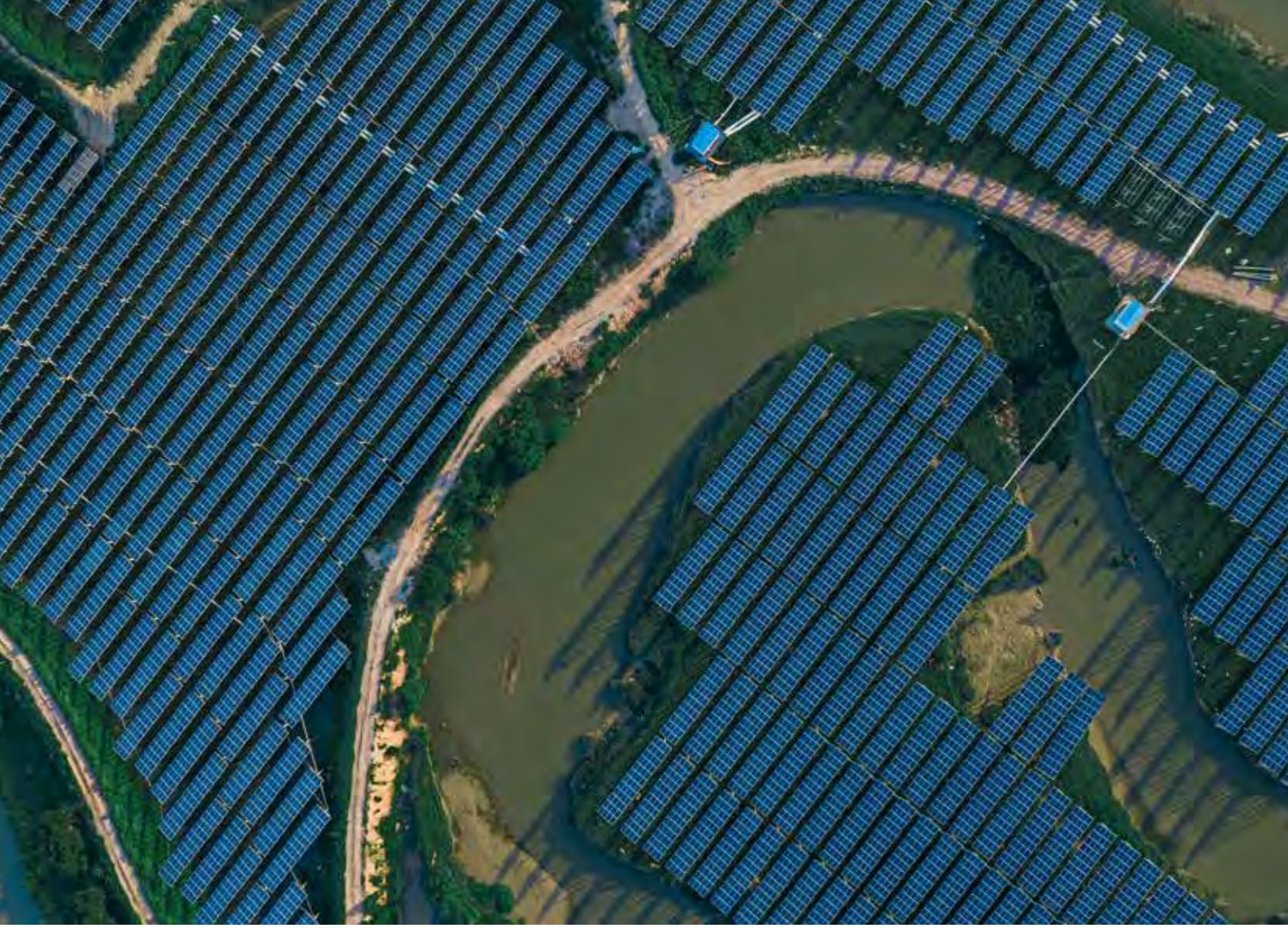
While unlocking significant future savings for consumers, the rapid uptake of small-scale solar has resulted in power system challenges in recent times. There is currently limited visibility of the collective impact of small-scale solar generation. This creates a challenge in system planning, particularly in coordinating and matching supply and demand. This minimum demand issue is covered in more detail in Section 2.3. The analysis in the System Plan points to VPPs as a potential mechanism for managing small-scale solar during the day.

Customers' demand from the power system would have been higher on a maximum day if customers had not used their solar.

Figure 12: Underlying demand and system demand on a maximum demand day in 2020



Underlying demand on a maximum demand day is higher than what is delivered from the system due to customers utilising energy from their small-scale solar installations. This has helped manage demand growth on the system, reducing generation and network costs.



1.3. 50% Renewable Energy Target by 2030

The Territory Government's Renewable Energy Target is 50% of underlying energy consumption met by renewable energy by 2030. Underlying energy consumption includes what is consumed from the power system and directly from small-scale rooftop solar.

Benefits of the Renewable Energy Target

- With the rise of renewables globally, the Territory can take advantage of innovations and emerging technologies.
- The timing is right. Many existing thermal generators are reaching end of life. The timeframe of 2030 coincides with the expected retirement of thermal generators. This provides a rare opportunity to replace existing technology with a mix that includes low-cost renewables.
- There is increased access to low-cost renewable solar in the area. The 2027 to 2030 period is the optimal time to replace the assets with lower cost renewables, such as solar.
- Government credit impact scores (e.g. Moody's) and international investors and financiers now consider how governments are addressing environmental considerations.
- As the Territory Economic Reconstruction Commission found, the integration of renewables (to advance decarbonisation efforts) can provide economic opportunities.
- Decarbonisation presents an opportunity for the Territory as part of an overall Australian economy approach. As businesses recover from the impact of COVID-19, they are rebuilding and adapting their business models in ways that aim to be future-proof, including carbon neutrality.
- Global commitments to net-zero emissions are increasing. Alongside government commitments, businesses are moving quickly to cement and promote market positions delivering carbon-neutral products and supply chains.
- Consumer demand is driving business to report on their carbon footprint and demonstrate carbon neutrality. Financial markets are starting to price in risks associated with transitioning to a net-zero economy.[11] Many of the largest banks have stopped lending to high-carbon industries, such as thermal coal.[12]

This System Plan provides information that guides where, when, what and how the Darwin-Katherine Electricity System will achieve the 50% Renewable Energy Target by 2030.

1.4. Drawing on national approaches

Most Australian states and territories are pursuing renewable targets for their electricity systems. While each jurisdiction differs in timing and magnitude, a consistent theme has been the need for governments and institutions to set pathways to guide industry.

Historically, governments acted as the central decision-maker for the electricity sector, including making investments in operating assets. This paradigm has shifted. Renewable technology is generally smaller scale, opening up opportunities for customers and private investors to drive investments. Industry, investors and shareholders are driving the focus on lowering emissions and increasing renewable energy.

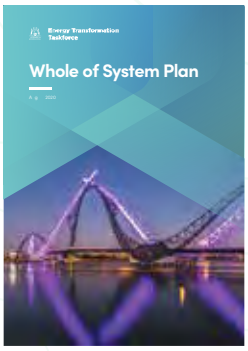
However, there is a still a need for governments to signal the optimal pathway, bringing together analysis and information. Coordinated planning and decision-making provides opportunities to deliver cleaner, lower cost and more reliable energy.

The Territory has the advantage of being able to draw on the experience of the National Electricity Market and Western Australia, recognising our unique circumstances and drivers, including geography and availability of alternative renewable technologies.

Figure 12 sets out some of the key findings in the Integrated System Plan for the National Electricity Market[13] and the Whole of System Plan for Western Australia.[14]

Figure 13: Comparing the Darwin-Katherine Electricity System Plan with approaches elsewhere in Australia







Type of power system

Very large interconnected system across eastern and southern jurisdictions	Expansive interconnected system in Western Australia	Small standalone system across the northern region

Renewables on system today

27% renewables on system	34% renewables on system	12% renewables on system

Viable renewable mix

Solar, wind, hydro, batteries, cogeneration	Solar, wind, cogeneration, batteries	Solar and batteries

Renewable Energy Target

Each jurisdiction has different target and timing	70% by 2040	50% by 2030

2. Analysis and scenario testing



The Darwin-Katherine Electricity System Plan brings together information, analysis and expert advice to identify a pathway to 50% renewables by 2030. Three plausible scenarios have been used to guide assessment of the electricity system challenges and technology necessary to achieve this goal.

2.1. Objectives and scope

The System Plan provides a clear pathway to achieve the 50% Renewable Energy Target by 2030. The System Plan is based on extensive analysis of the challenges of transitioning to 50% renewables, and the potential for new technologies to efficiently and cost-effectively support this transition.

The System Plan has been designed to be accessible to all stakeholders, explaining concepts rather than defining engineering solutions.

The System Plan charts the size and timing of energy infrastructure investments to 2030, based on achieving the following objectives.

1. Achieving the 50% Renewable Energy Target by 2030 under plausible scenarios.
2. Ensuring that the power system's security is maintained, including under extreme circumstances.
3. Focusing on low-cost opportunities that are technically feasible and timely in delivery.
4. Investments are compatible with future scenarios and technologies, or 'future proofed', recognising the need to evolve over time with changing circumstances.

Sequencing is integral to the System Plan – the Territory needs to be ready, positioned to respond quickly to changes, and be coordinated in our approach.

The planning horizon for the System Plan is to 2030. However, the Territory is also mindful that the pathway needs to be compatible with long-term development and technology opportunities beyond 2030 and to 2050, and must therefore be dynamic and organic.

The System Plan focuses on the investments and platforms required to achieve the 2030 target. While the System Plan has carefully considered the Territory Government's policy and reform agenda, it does not seek to subsume or replace the substantial reform work being undertaken by multiple government agencies.

Significant policy, market and regulatory initiatives are required to support delivery of the six focus areas. This includes resolving critical questions, such as the ideal mix of private and public investment, funding, market structures and optimal regulatory frameworks. Section 6.2 identifies the key elements of an implementation plan required to achieve the vision efficiently and within the timeframes.

The System Plan focuses on strategic issues and is not intended to address short-term power system operational requirements, replace existing technical guidelines or obviate the need for investment justifications. The expectation is that relevant government owned corporations and government agencies continue to meet their operational accountabilities, but within a shared strategic context.

2.2. Scenarios

Predicting the electricity landscape in 2030 is challenging due to the large number of unknowns, including energy usage patterns, population growth and dispersion, future new industries, technology glide paths and investment preferences and expectations. The pace of change can be rapid.

Three scenarios have guided the scoping of the possible electricity industry landscape in 2030. These scenarios recognise recent forecasts produced by the Utilities Commission of the Northern Territory (Utilities Commission), including on energy, new and retiring generation, and small-scale solar.

The System Plan also considers what the Darwin-Katherine electricity system could look like beyond 2030, given the government's vision of a greatly expanded economy by 2030, and requiring a 1GW power system (4 times today's demand) towards 2050.

In this chapter, we discuss each of the scenarios and provide accompanying data. Figure 14 presents the underlying energy consumption forecasts. Figure 15 presents the maximum demand forecast for each scenario. Figure 16 presents the total amount of additional installed solar (MW) required to meet the 50% Renewable Energy Target for each scenario. Figure 17 shows the relative split of small and large-scale solar for each scenario.

Scenario 1 – From Little Things

From Little Things holds open the possibility of small-scale solar continuing to drive the transition to renewables in the Darwin-Katherine region. It also assumes a lower energy and demand growth outlook than the Utilities Commission's forecasts.

Underlying energy consumption grows at a modest 0.47% each year, on average, over the next decade.

This scenario assumes that small-scale solar uptake is strong, growing from about 80MW in 2020 to almost 220MW by 2030. This is higher than the Utility Commisssion's current projected forecast of small-scale solar take up, 2030, but still reflects a declining trend compared to the current average rate.

Despite the strong small-scale solar uptake, the system still requires 190MW of large-scale solar to meet the 50% Renewable Energy Target by 2030.



Scenario 2 – Seek Different

Seek Different is a new paradigm from the current system, where large-scale solar is the primary mechanism for delivering the 50% Renewable Energy Target. This is the central scenario on which the System Plan is primarily based.

Seek Different has higher energy consumption and maximum demand forecasts than Scenario 1. The forecasts align with the Utilities Commission's forecasts of approximately 0.97% each year over the next decade.

Under this scenario, about 240MW of large-scale solar would be installed between 2020 and 2030. Small-scale solar installation slows, due to a level of market saturation, at a level lower than in Scenario 1. Small-scale solar doubles from about 80MW in 2020 to almost 160MW in 2030. This scenario paradoxically requires slightly less total investment in solar, due to the relatively higher production of solar generation of large-scale solar that follows the sun through the day.



Scenario 3 – Sunshine for Sale

Sunshine for Sale is aligned to the Territory Government's vision of a $40 billion economy by the end of the decade. Demand for electricity grows to four times current demand as new industries including advanced manufacturing, data centres and mines located in our region.

Under this scenario, we also see a marked acceleration in electric vehicle use, adding to network demand. Underlying energy consumption grows steadily to 2025, and then accelerates significantly between 2026 and 2030. This equates to an average annual increase of 6.31% over the next decade.

Small-scale solar increases from about 80MW today to almost 220MW by 2030, consistent with the From Little Things scenario..

Large-scale solar is deployed at mass scale with about 370MW deployed from 2020 to 2030.



Darwin-Katherine toward 2050

While the System Plan focuses on 2030, it also contemplates what the Darwin Katherine Electricity System may look like towards 2050.

The System Plan is compatible with a vision of a power system that delivers almost 4 times today's demand, a 1 GW system.

The Darwin Katherine Electricity System will need to accommodate large loads from new industry, including data centres, advanced manufacturing, renewable hydrogen for export, and electric vehicles. The System Plan has to be agile and nimble to be able to efficiently and quickly expand to meet demand options beyond the modeled scenarios.

Within this context, the System Plan looks to the Territory Government's vision of net-zero emissions by 2050, with expectations for a 'clean energy' pathway beyond 2030 to ensure that decisions in the medium term are future-proofed towards this vision.

The analysis suggests that in the longer term, emerging renewables technologies such as green hydrogen or transporting solar energy over long distances will be necessary.



Figure 14: Underlying annual energy consumption in each scenario

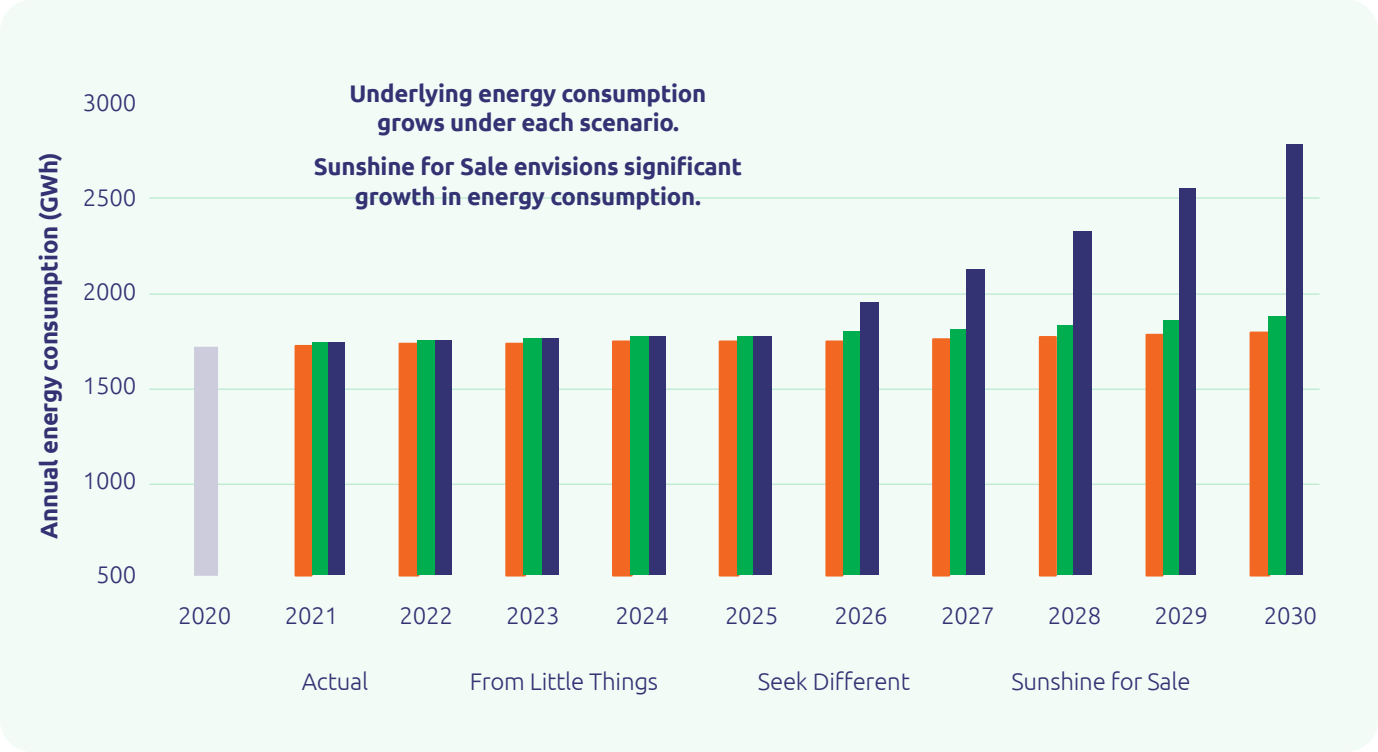


Figure 15: Maximum demand forecast for each of the scenarios

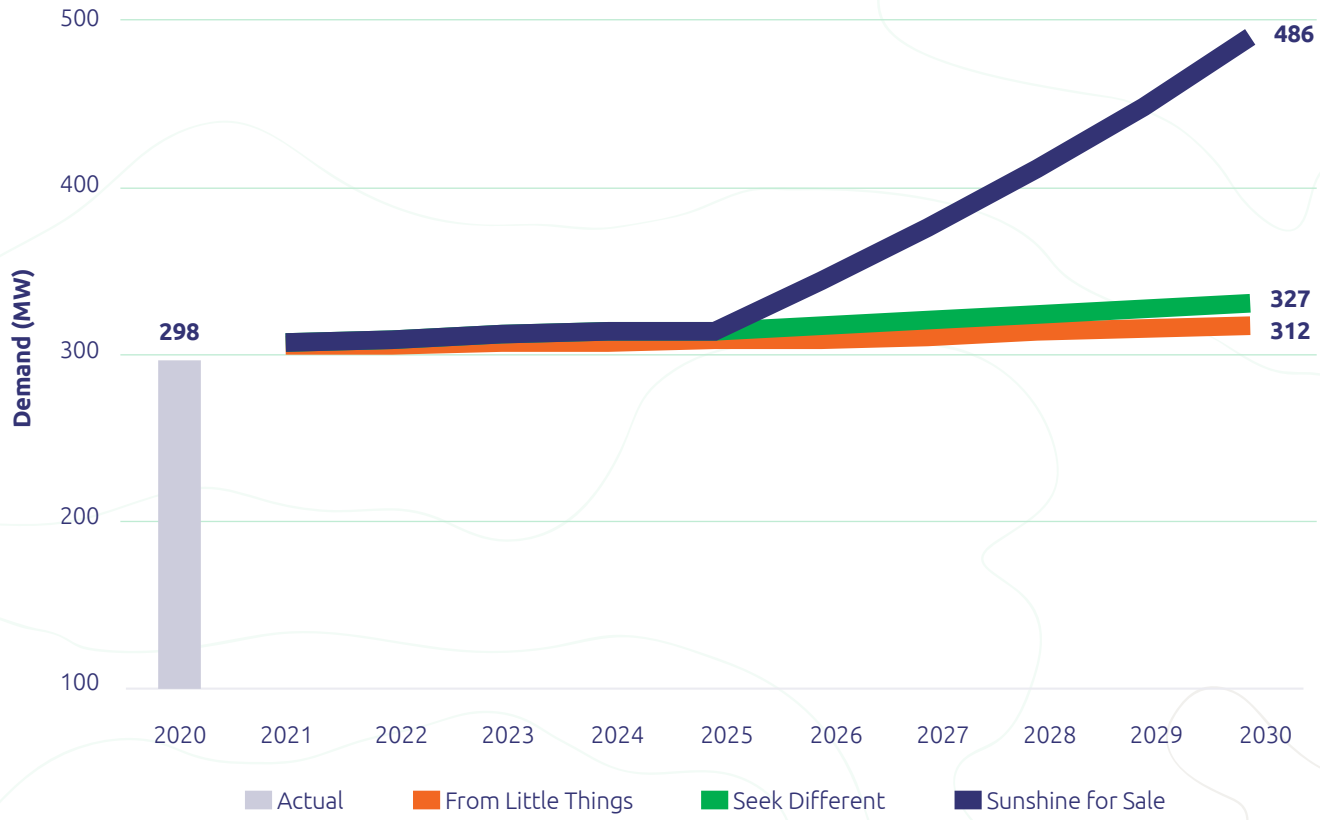


Figure 16: Total amount of installed solar (MW) required to meet the 50% Renewable Energy Target for each scenario

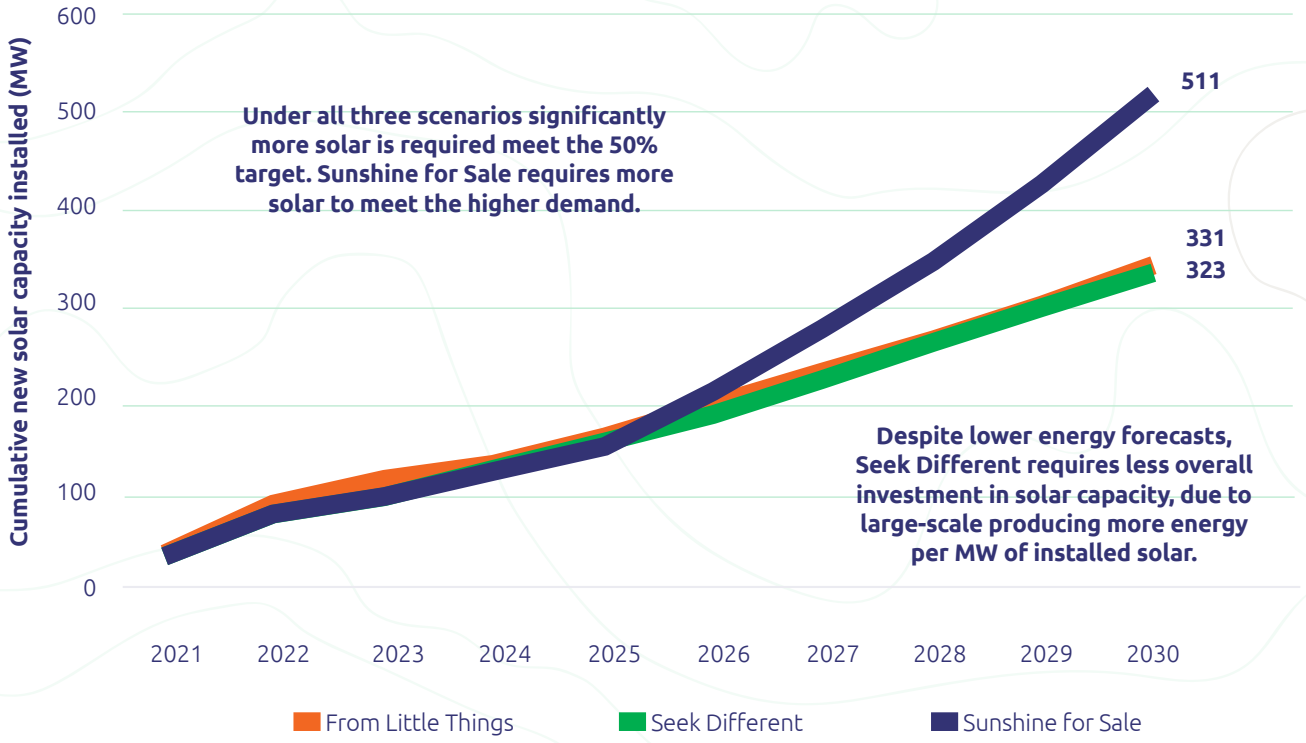
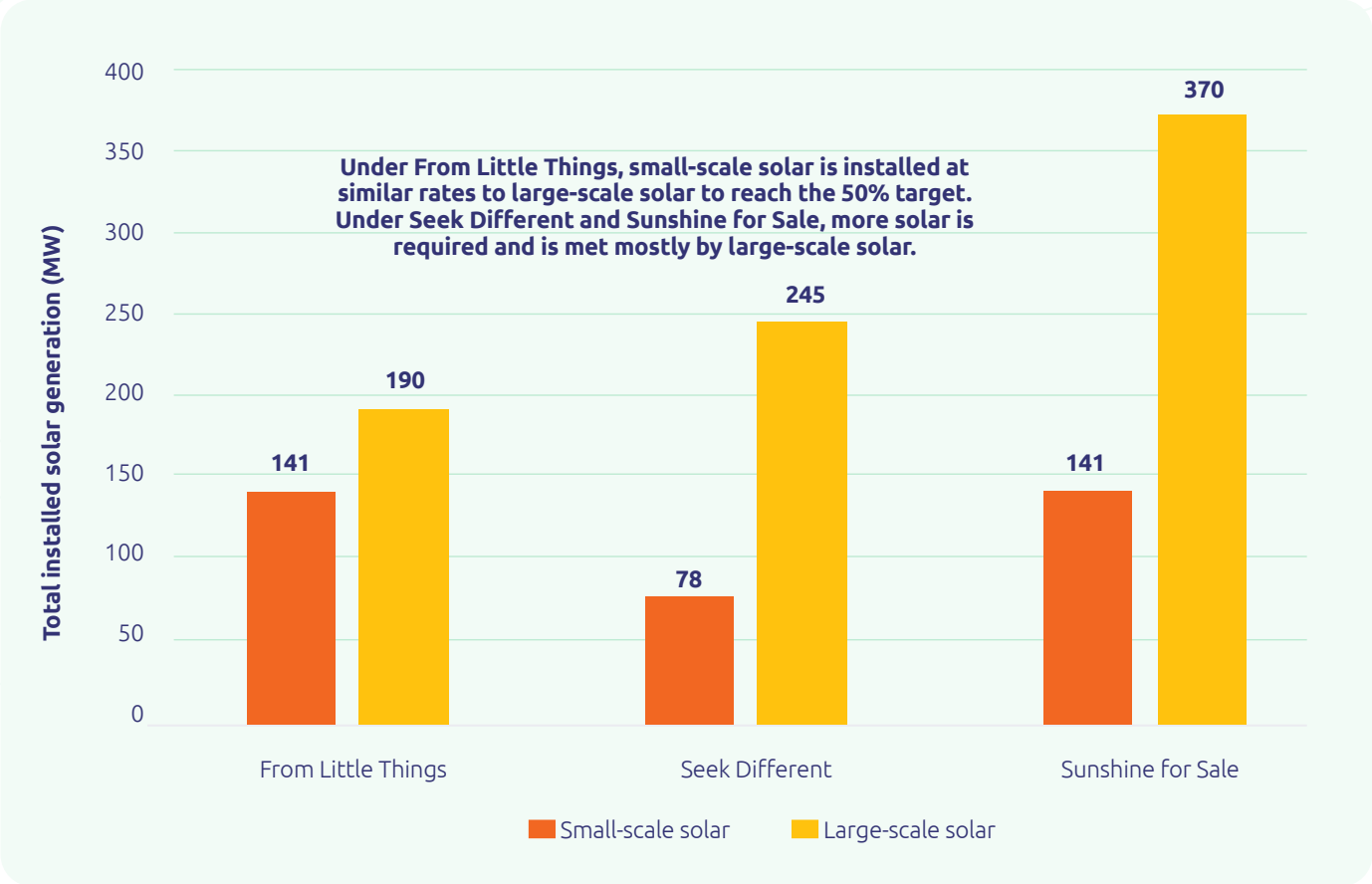


Figure 17: Relative split of new small and large-scale solar for each scenario to reach 50% target



2.3. Bringing together information and data

The System Plan brings together industry knowledge and expertise to inform the government's internal analysis and modelling.

The internal analysis focused on addressing the challenges with transitioning to the 50% Renewable Energy Target. The size and timing of investments for each scenario to 2030 was identified, and sought to recognise and address specific challenges.

Experienced industry advice guided the identification of issues and solutions, and was used to verify the government's findings.

- Ekistica, a power system technical advisory firm, helped inform the analysis of the costs of a Renewable Energy Hub for large-scale solar, solutions to maximise committed generation, the optimal size of battery storage and impacts of demand management, and advice on power system needs towards 2050.
- GHD, experienced in essential system services for power systems, provided advice on the security needs of the Darwin-Katherine Electricity System under a changing generation mix, and on the capacity of emerging technologies.
- CutlerMerz, a technical economic and management advisory firm on transformation of power systems, provided a view on the benefits of VPPs in the Darwin-Katherine system, and the key steps to ensure successful implementation.
- Dynamic Analysis, an advisory firm in network regulation, electricity price modelling and electric vehicle transformation, provided advice on annual network costs associated with the planned Renewable Energy Hub, and impacts of electric vehicles on demand management and energy affordability.

2.4. Identifying the challenges

The analysis indicates that there are three key challenges in the development of a 10-year pathway.

1. Meeting demand

The bulk of energy is currently generated by thermal machines that can run 24 hours a day and 'on demand'. The system has been designed to provide energy during peak times, even with the loss of a major generation plant.

The challenge for a 50% Renewable Energy Target is how to meet demand when renewable generation is not available. For example, solar is not available overnight, including over the peak evening periods.

The System Plan incorporates an assessment of the vulnerability of the proposed generation mix in 2030, particularly in the context of this evening peak. Section 5.2 demonstrates that thermal generation and battery storage can meet peak demand in 2030, even with a major generator out of service.

An assessment was also undertaken of the ability for renewables to meet demand in monsoons and cyclones where solar generation may be compromised by continuous periods of cloud cover. Section 5.2 shows that





the generation mix in 2030 can meet maximum daytime demand under monsoon conditions through thermal generation and battery storage.

2. Managing security

The current power system has inbuilt services to keep the system secure, including frequency and voltage control, and system strength.

Frequency control

Frequency control ensures the power system can constantly maintain a demand-supply balance, even following a major disturbance. Thermal generation currently provides a number of frequency control services, including inertia and spinning reserve.

Due to their mass, following a major disruption to the supply- demand balance, thermal generators have an inherent instantaneous inertial response that resists the disturbance until the control system can respond. Solar generation systems do not have the same inherent support.

A key challenge is ensuring the system has sufficient frequency services on low-demand days in the dry season. The extreme day is termed a 'minimum demand' day when operational demand is at its lowest.

On minimum demand days, small-scale solar produces high levels of electricity due to greater availability of sun, particularly in the dry season. At the same time, demand is relatively low as airconditioners are not required in cooler and less humid conditions.

Currently there are i nsufficient tools to control small-scale solar to maintain the demand-supply balance and protect the security of the power system. As small-scale solar uptake increases, less load is met by thermal generation. Once thermal generation drops below a certain threshold, there is a risk of insufficient inertia to manage a major system disturbance.

For this reason, the System Plan analyses how minimum demand is likely to fall by 2030, and what solutions are possible to maintain system security. Figure 18 shows the likely extent to which minimum demand could fall below the level of load required by machine generation by 2030.

New high spec security batteries could provide the equivalent inertia service of a large thermal machine. Therefore, with security batteries, we would require less operational load to securely operate thermal generators and provide these security services.

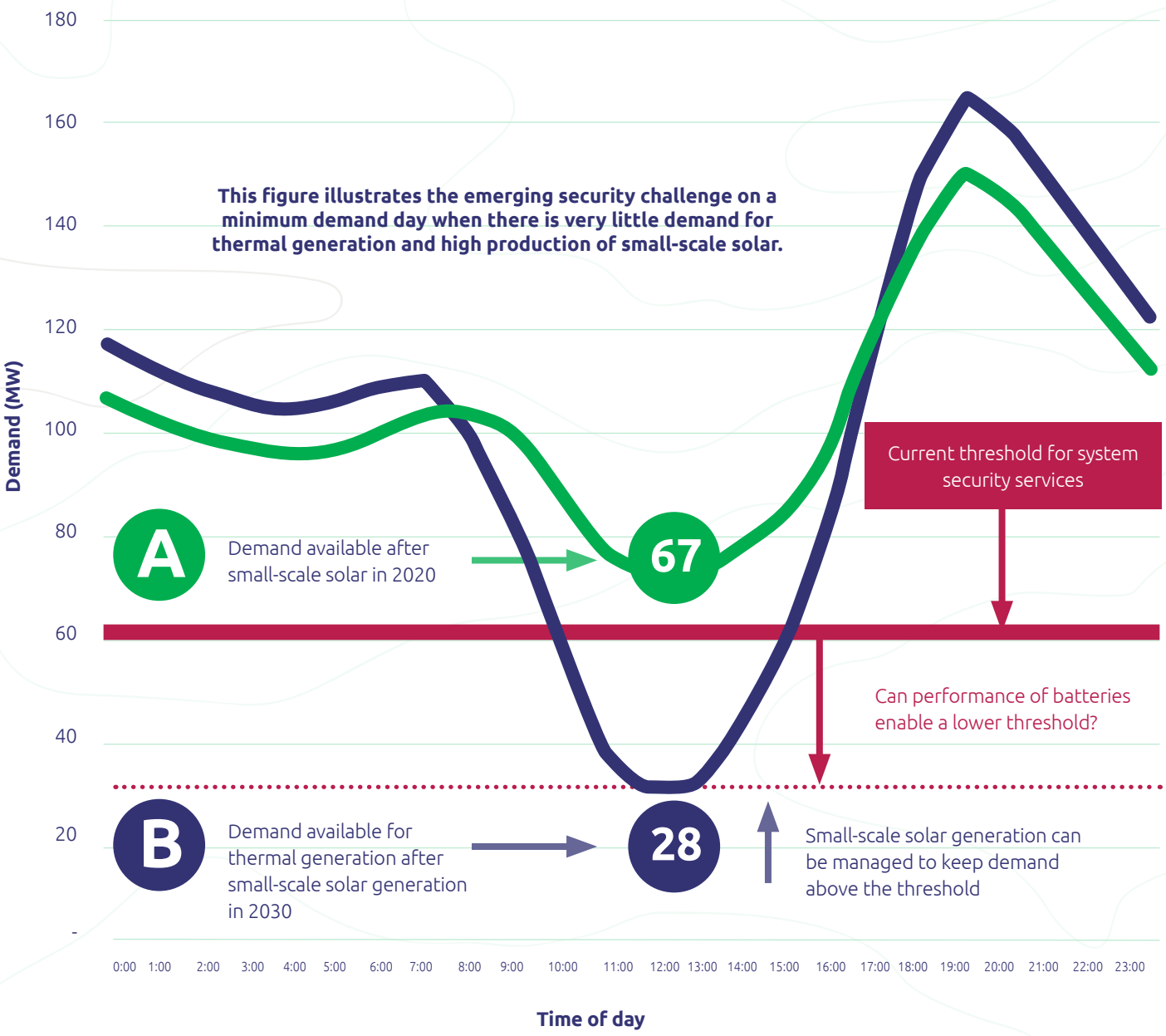
The approach to how broader frequency services can be provided under a 50per cent renewable scenario was also examined. These are the primary and secondary system response services that halt and stabilise the change in frequency following a system disturbance.

These services are currently provided by the thermal generators through 'spinning reserves'. In effect, this is surplus generation to regulate changes in demand and manage contingency events. This is costly to operate. The business case justifying the installation of the first high spec battery demonstrates that the technology should provide frequency control services at a substantially lower cost than spinning reserves. This is discussed further in Section 3.4.





Figure 18: Maintaining security services on a minimum demand day by 2030



A The power system requires about 60MW of thermal generation in the system to provide inertia services (red solid line). On the minimum demand day in 2020, the available demand (green line) approached the 60MW threshold with an increase in small-scale solar generation.

B By 2030, the growth in small-scale solar means that the available demand after small-scale generation may drop below 30MW (blue line). Section 3.4 discusses how the new high spec security batteries provide sufficient inertia services to drop the threshold to 30MW (red dotted line). Section 3.5 demonstrates how the Virtual Power Plant will help coordinate solar generation so that the available load can stay above 30MW by 2030.



Image supplied: Power and Water Corporation

Voltage control

Voltage is the 'pressure' of electricity. On the transmission network it supports system security particularly following a disturbance. On the distribution network, it ensures customers' electrical appliances continue to operate safely and efficiently and are not impacted by system disturbances.

Currently, thermal generators on the system provide most of the support to maintain voltage control. The Generator Performance Standards (GPS) require voltage support on large-scale solar generators which will assist in mitigating the risk when thermal generation retires from 2027 onwards. For this reason, this is not identified as a strategic need requiring new investment over the next decade, provided the GPS requirements and other current operational requirements stay in place.

If we take no proactive action, elements of the distribution network may be adversely impacted by increasing small-scale solar. The System Plan investigates the role of a VPP to help aggregate and optimise small-scale solar. This may also help address emerging voltage issues. The Power and Water Corporation's regulated network business is best placed to determine the operational solutions to address these issues, potentially as part of its upcoming 2024-29 regulatory determination process.

System strength

System strength is the third element of system security. This is a local phenomenon that helps the system maintain stability during a disturbance. System strength is also currently provided via thermal generation.

System strength will decline as large-scale solar displaces thermal generation towards the end of the decade. In Section 5.2, the System Plan notes that modern generation solar systems and batteries may address these challenges. However, the System Plan has not expressly included investments to address this issue. It is not an immediate concern but this issue will need to be explored more deeply in the updated 2023 System Plan.

3. Minimising cost

In addition to system security and reliability, the Darwin-Katherine Electricity System Plan also recognises the imperative for a low-cost pathway to achieve the 50% target. This requires a comprehensive assessment of options and opportunities for synergies.

Mechanisms to address key areas of focus

- Reduce connection and transport costs of renewable generation: For example, the plan for a Renewable Energy Hub aims to co-locate solar farms to shared connection assets close to existing transmission infrastructure and near demand for energy.
- Maximise generation output from renewable generation. This includes maximising the availability of large-scale solar that can be exported onto the network, storing and discharging surplus solar via batteries, and developing virtual power plants to help aggregate and coordinate household energy production and usage to best effect.
- Use lower cost methods to secure the network and improve performance. Alternatives to traditional technologies to secure the network have been investigated, including emerging technologies such as batteries to secure the network, maximise generation from solar, and store and discharge energy from solar generation.

3. Focus areas



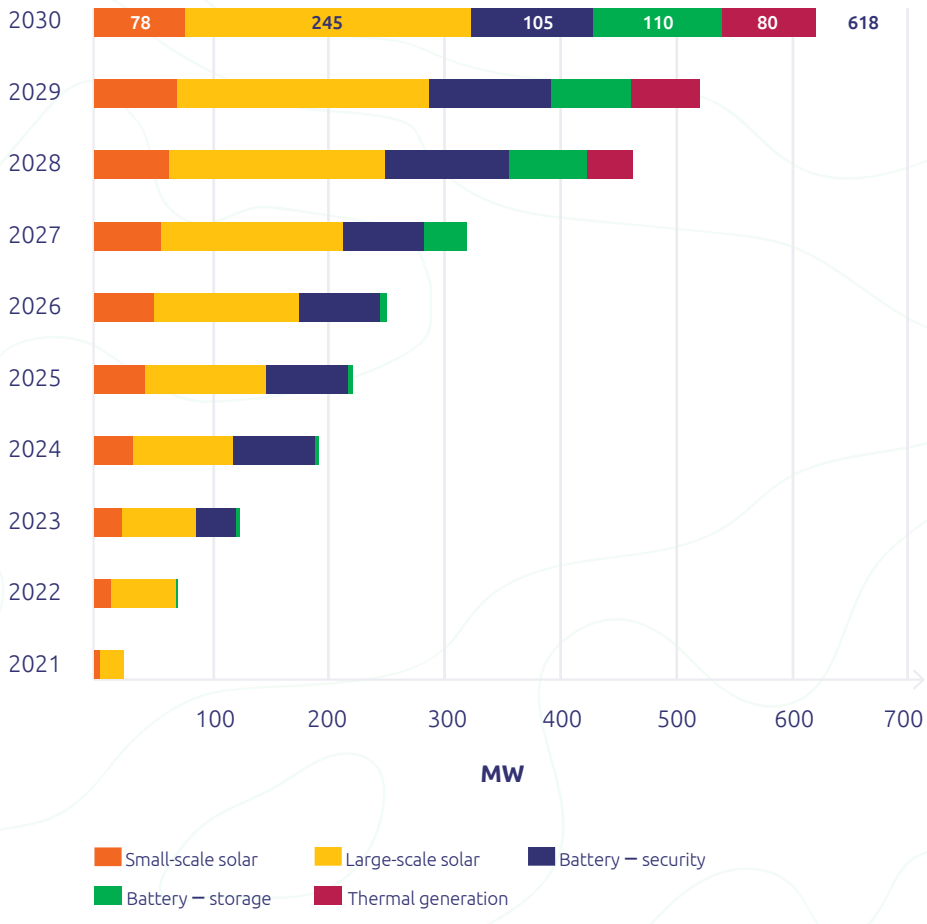
Image supplied: Power and Water Corporation

Six key focus areas will help achieve the 50% Renewable Energy Target reliably and securely at low cost. The focus areas include investing in solar, battery storage, thermal generation and high spec security batteries. The System Plan also identifies the need for a new Virtual Power Plant to coordinate small-scale solar, and demand management initiatives to maximise solar energy production.

Chapter 3 identifies the mix and scale of investments to reach the 50% Renewable Energy Target securely and at low cost. Figure 19 shows the cumulative capacity of new investment identified in the System Plan based on the Seek Different scenario discussed in Section 2.2. The remaining sections of the chapter identify each of the six focus areas in the System Plan.

In identifying the potential mix, scale and timing of investments, the System Plan aims to maximise opportunities for private investment.

Figure 19: Cumulative new capacity installed under focus areas for Seek Different



3.1. Install 320MW of new Solar by 2030

The System Plan shows that solar generation is the most viable approach to achieving the 50% Renewable Energy Target by 2030[15]. The sections below discuss analysis and modelling to support the need for 320MW of new solar by 2030.

Why solar?

As highlighted in Figure 20, solar irradiance in the Darwin-Katherine region is relatively high compared to other Australian jurisdictions. This means that each solar panel installed is more effective at generating energy. The Territory also has relatively more land to install large-scale solar farms close to the power system.

However, unlike other states and territories, the following alternative sources of renewable generation are either not as available, cost-effective or viable at scale.

- **Wind**: There is potential for wind energy in the Barkly Region that will be analysed and assessed for its potential to complement solar generation. The analysis shows that wind is not economically viable at the forecast demand levels expected in 2030 but could be viable when demand increases in the future.
- **Pumped hydro** – There is no viable location for pumped hydro in the region, and transportation costs would be likely be prohibitive and inefficient at our current level of demand.
- **Renewable hydrogen:** The region has significant resource capability for a renewable hydrogen industry. The Territory's Renewable Hydrogen Master Plan talks to the Territory's approach to advancing this opportunity[16]. Renewable hydrogen has great potential beyond 2030 to meet energy needs.
- **Biofuels:** Biofuels provide an opportunity to turn household, industrial and agricultural waste into energy. This is a growing source of renewables and may be a viable complement to the Territory's renewable mix as technology advances, availability increases and costs reduce.
- **Geothermal:** There is long-term potential for geothermal energy in the Territory but it is relatively immature at present. It is unlikely this status will change in the medium term to contribute towards the 2030 target.

Required capacity of solar

Under the Seek Different scenario, about 320MW of new solar is required by 2030. This is in addition to the 80MW of small-scale solar currently installed.

Solar generation is only possible when the sun shines, so solar generation is typically strongest in the middle of the day when the sun is overhead, with less generation in the early morning and late afternoon.

In determining the solar generation capacity required to meet the 50% Renewable Energy Target, analysis indicated that about 58% of underlying demand on an average day was between 6am to 6pm. Therefore, the System Plan seeks to maximise solar generation during these times, recognising that a minimum level of thermal generation is still required to ensure system security.

Large-scale solar will lead

Under the Seek Different scenario, small-scale solar is forecast to double, from about 80MW in 2020 to more than 155MW by 2030. Consequently, 245MW of new large-scale solar will be necessary by 2030.

Large-scale solar has benefits that efficiently reduce the necessary level of installed capacity. The analysis used technology that is designed to 'follow' the sun during the day (single axis tracking) in order to maximise solar generation. In contrast, smaller-scale solar panels are generally fixed and, therefore, less productive. The relative effectiveness of large and small-scale solar production is compared in Figure 21.

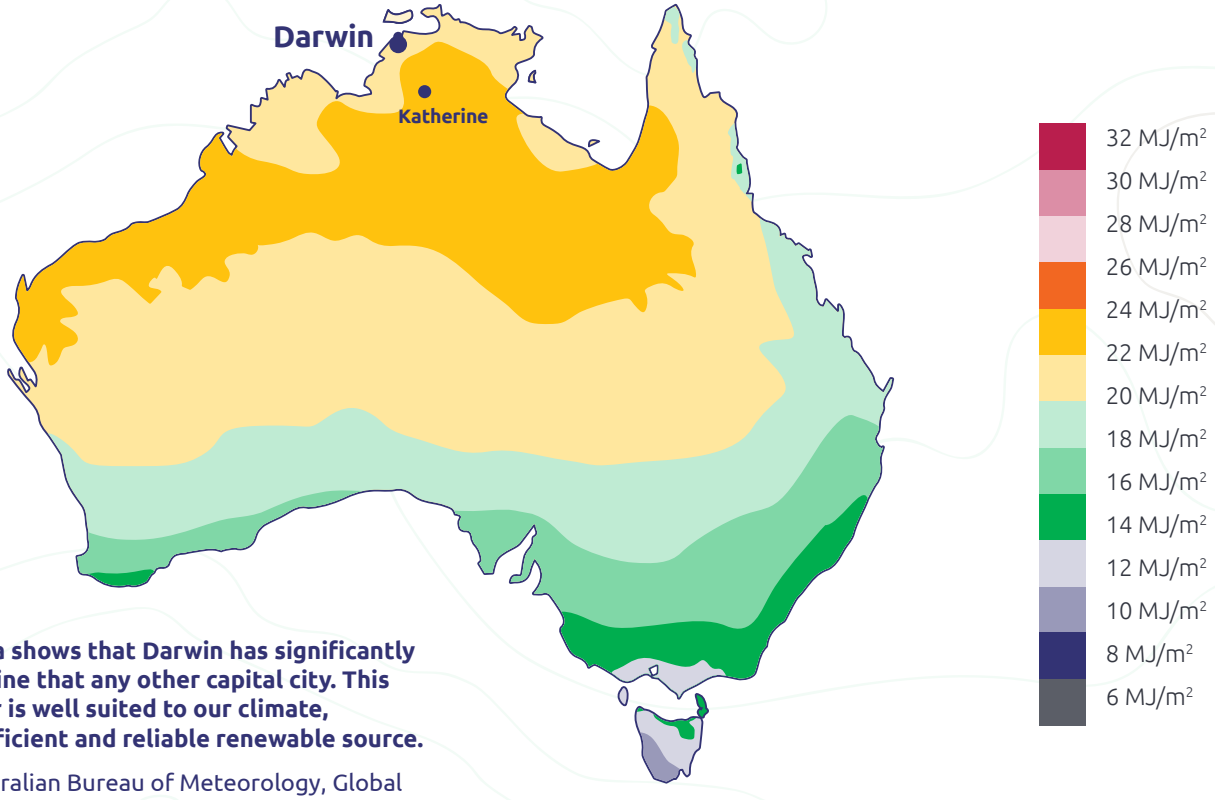
Large-scale solar will need to meet the current generator performance forecasting standards to ensure the security capabilities of the system are maintained.



Image supplied: Power and Water Corporation



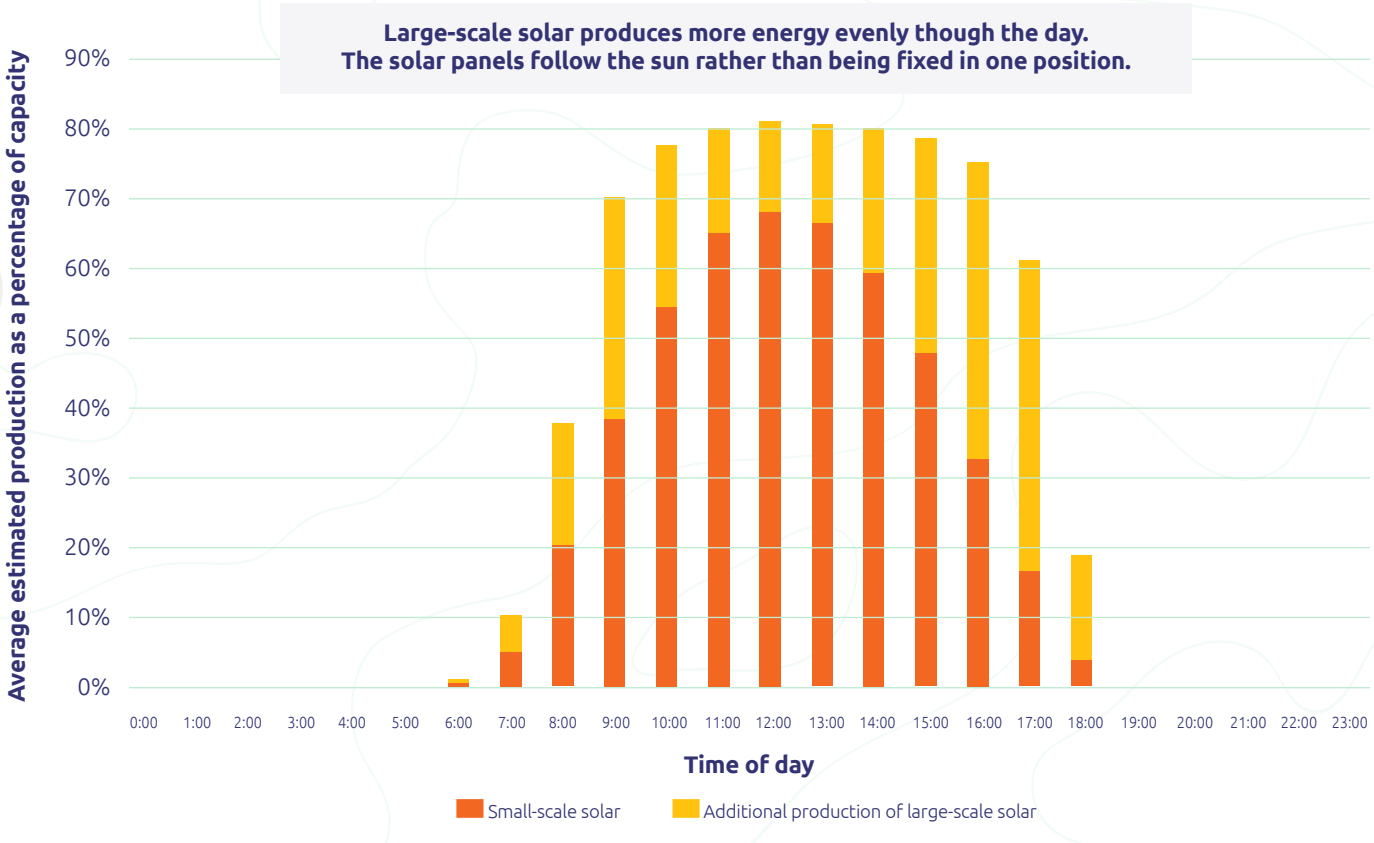
Figure 20: Solar irradiance in Australia



Weater data shows that Darwin has significantly more sunshine that any other capital city. This means solar is well suited to our climate, and is an efficient and reliable renewable source.

Source: Australian Bureau of Meteorology, Global Solar (MJ/m2) during 1 June 2020 to 21 May 2021

Figure 21: Relative effectiveness of large-scale single tracking array, compared to small-scale fixed axis tracking



Renewable Energy Hubs to coordinate large-scale solar

The System Plan encourages the development of Renewable Energy Hubs, which are solar farms co-located in an area close to load and transmission capacity. Renewable Energy Hubs maximise generation potential and reduce costs.

Benefits of the Renewable Energy Hub

- **Leverage capacity on existing transmission network:** The Renewable Energy Hub would connect to the Channel Island to Hudson Creek 132kV high-capacity transmission line (see Figure 22). This would have sufficient capacity to transfer the generation as the expected generators retire at the Channel Island power station. This provides an opportunity to transport large-scale solar using existing energy infrastructure.
- **Maximises generation from solar:** Solar farms connected to the Renewable Energy Hub would have a secure, high capacity network connection, with the best opportunity to maximise sent out solar energy (generation dispatch).
- **Lower connection and development costs:** Solar farms are able to share development and connection costs, greatly reducing necessary upfront investment costs.
- **Potential to unlock benefits from shared assets:** Shared assets could extend to firming batteries and technology to meet GPS requirements, or storage batteries to further reinforce dispatchability and system performance. This sharing may result in the efficiency of large-scale development being shared across smaller connections.
- **Caters for the future power system:** Importantly, the hub provides a 'least-regrets' first step towards developing the larger power system suitable for 1GW of demand. The Renewable Energy Hub may also become an important node on the power system to connect and transmit high volumes of energy into and around the Darwin-Katherine region. This is discussed in more detail in Section 5.5.

The System Plan contemplates an initial Renewable Energy Hub optimally sized between 180 and 230MW of large-scale solar. This potentially aligns with the capacity on the existing Channel Island to Hudson Creek 132kV line without any need to invest in uprating the existing line.

Transmission connection costs are expected to be in the vicinity of $80 million (real dollars in 2020) consisting of diversion and extension of the 132kV transmission lines, construction of a 132/22kV substation, site studies and project development overheads. The figure does not include land costs.

Careful consideration will need to be given to how the Renewable Energy Hub concept can be advanced. Key matters include site identification, site design, delivery approach, timeframes and administration. Figure 22 shows a map of the Renewable Energy Hub concept.

Maximising generation of committed solar

The System Plan forecasts about 60MW of committed large-scale solar will connect to the DKTL by 2022. The solar generation will be used to meet energy needs in Darwin, flowing mostly in one direction.

The security limit into Darwin from the DKTL is currently about 40MW, due to system limitations and the line being a single contingency risk. This limits the level of renewable generation that can be securely sent out from the new committed generation unless demand grows near the location of the solar farms.

Analysis undertaken to increase the renewable energy available from the DKTL involved consideration of four options.

- **Option 1:** Limit generation on the DKTL line to maintain existing security. This may result in about 15% of the renewable generation being curtailed. No material system costs would be incurred under this option.
- **Option 2:** Apply a risk-based approach that enables more generation but at a higher risk of system disruption, compared to the present. No material system costs would be incurred under this option.
- **Option 3:** Install a new high spec security battery at Channel Island where the DKTL line connects to Darwin to provide the necessary level of security services. This would result in only a small amount of generation being limited (about 4%), and with no increased risk of system disruption.
- **Option 4:** Partially duplicate the existing transmission line from Channel Island power station to Pine Creek substation. This option would allow for almost all generation to be securely sent out with no increased risk of system disruption. However, system costs will be significant.

System Plan analysis demonstrates that the high spec security batteries provide the best value of the four options.

From a cost-benefit perspective, there is evidence to suggest that a battery would provide a net benefit, including a reduction in the volume of curtailed solar generation. The System Plan also assessed the benefits from the first high spec battery (to be commissioned by 2023), which indicates material annual benefits associated with the more efficient delivery of security services. The combination of these benefits are expected to exceed the cost of the battery.

High spec security batteries are planned to be utilised to support system security as thermal generation retires. This means there is an opportunity for a single solution to provide system performance improvements that address the DKTL contingency risk and provide security.

Advancing the second security battery will unlock lower energy costs for customers, maximise the renewable generation on the system, and improve the security of the system.

System Plan analysis shows that there is limited benefit to connecting large-scale solar directly to the DKTL beyond the 60MW committed. It is also likely that future investors will favour the Renewable Energy Hub rather than connect to the DKTL or other readily accessible areas. This is because the costs of connection will be significantly lower, and the generation availability would be maximised.

Figure 22 -- Proposed Renewable Energy Hub



3.2 Install 110MW (600MWh) of storage batteries

Unlike other states and territories, the Territory is reliant on solar as the primary renewable source to meet the 50% Renewable Energy Target. Solar is low cost but is limited because it only produces energy during the day when the sun is shining.

The System Plan analysis shows that 58% of underlying demand on a typical day in 2030 will occur during the sunlight hours of 6am to 6pm. However, even with an additional 320MW of solar installed, this will result in solar supplying only 41% of underlying demand during this time, due to:

- solar generation being relatively lower in the early morning and late afternoon, particularly for small-scale solar installations that do not follow the sun
- thermal generation being needed during the day to ensure system security.

The System Plan identifies storage batteries as the solution to boost renewables from about 41% to 50% by 2030. The batteries can capture surplus solar produced in the middle of the day, and release the energy when the sun is not shining in the evening and overnight.

To achieve the 50% target,110MW of installed battery capacity, providing about 600MWhs of battery storage each day, is required. This is sufficient to store all surplus solar on a maximum demand and average demand days, but will not store all surplus solar on a minimum demand day, as seen in Figure 23.

In terms of the type and location of battery storage, 100MW of large-scale batteries will be required to deliver most of the needs. The batteries would most likely be co-located in the Renewable Energy Hub as there will be sufficient capacity in the transmission network to fully discharge the stored energy.

At the same time, home and community batteries can play an important role in coordinating small-scale solar generation and addressing local constraints on the network. The analysis indicates that about 10MW of small-scale batteries will complement large-scale solar by 2030. This will be operated through a VPP.

The capacity of storage batteries to contribute to other system security services, such as Essential System Services, has not been considered at this stage.

The System Plan recognises that batteries can also unlock operational efficiencies for thermal generation. Thermal generation can be better optimised when machines produce across an 'even load' rather than ramping up and down to meet demand. Batteries are more efficient at meeting fluctuations in demand and, therefore, provide a valuable balancing tool. This can be seen in Figure 24.

As noted in Section 3.6, there are significant opportunities to use demand management to shift energy consumption into the middle of the day, reducing the need for storage batteries. There is further opportunity to reduce investment if customers are more energy-conscious and are able to shift consumption from the evening towards the middle of the day.

3.3. Refresh thermal generation

The planned retirement of a substantial fleet of thermal generation by 2030 provides a rare opportunity to efficiently pivot the system to renewable generation.

Retire aged generators (200MW)

Based on data from the Utilities Commission, the System Plan forecasts the expected timeline for retiring thermal generators on the Darwin-Katherine Electricity System.

Nine of the 19 thermal generation plants are expected to be decommissioned by 2030, commencing in 2027. This represents about 200MW of the 425MW of the current thermal generation capacity, or about 45%. The total expected change in thermal generation capacity is outlined in Figure 25.

The System Plan recognises that generation retirement timing may change, which impacts the pathway identified in the plan. As the System Plan is expected to be reviewed and updated biennially, any such changes will be identified and the System Plan adjusted accordingly.

Install new agile thermal generation (80MW)

The System Plan identifies a need for energy when the sun is not shining. Under all scenarios, evening and night demand is expected to increase compared to current levels of demand.

About 80MW of new thermal plant will be required between 2027 and 2030 to securely meet overnight demand. This is sufficient to meet energy on a maximum demand night, even with a major generator out of operation.

The System Plan expects the 80MW capacity could be met through 4 machines, each with a capacity of 20MW. These machines can be smaller and faster responding than today's fleet of thermal generation for the following reasons.

- Thermal machines will operate mainly at night, as solar will provide most energy in the day. The changing role of thermal generation is seen in Figure 26.
- Smaller machines have a higher degree of flexibility and lower costs, including installation opportunities 'deeper' in the network, reducing potential network costs. This may also assist with localised system strength issues as identified in Section 2.4.
- Smaller machines are less likely to introduce new or larger contingency situations to the system, meaning additional services will not be required to secure individual generation units.
- Smaller machines are capable of efficiently operating at lower system loads, maximising opportunities for other renewable energy generators.
- Faster starting and responding machines are better suited to a future power system that has a more volatile outlook for short-term demand and supply, which needs to be balanced.
- Batteries limit the need for heavy machines to provide security, providing opportunities for lower cost, efficient thermal generation.

The System Plan also identifies an opportunity for a new thermal plant to be fuelled from renewable hydrogen, offering the opportunity to transition and, ultimately, convert capacity to more renewables as the technology becomes viable. We note Trials are already planned at Tennant Creek Power Station on renewable hydrogen blending technology.[17]

Figure 23: Battery storage (MWh) on an average day (Central Scenario)

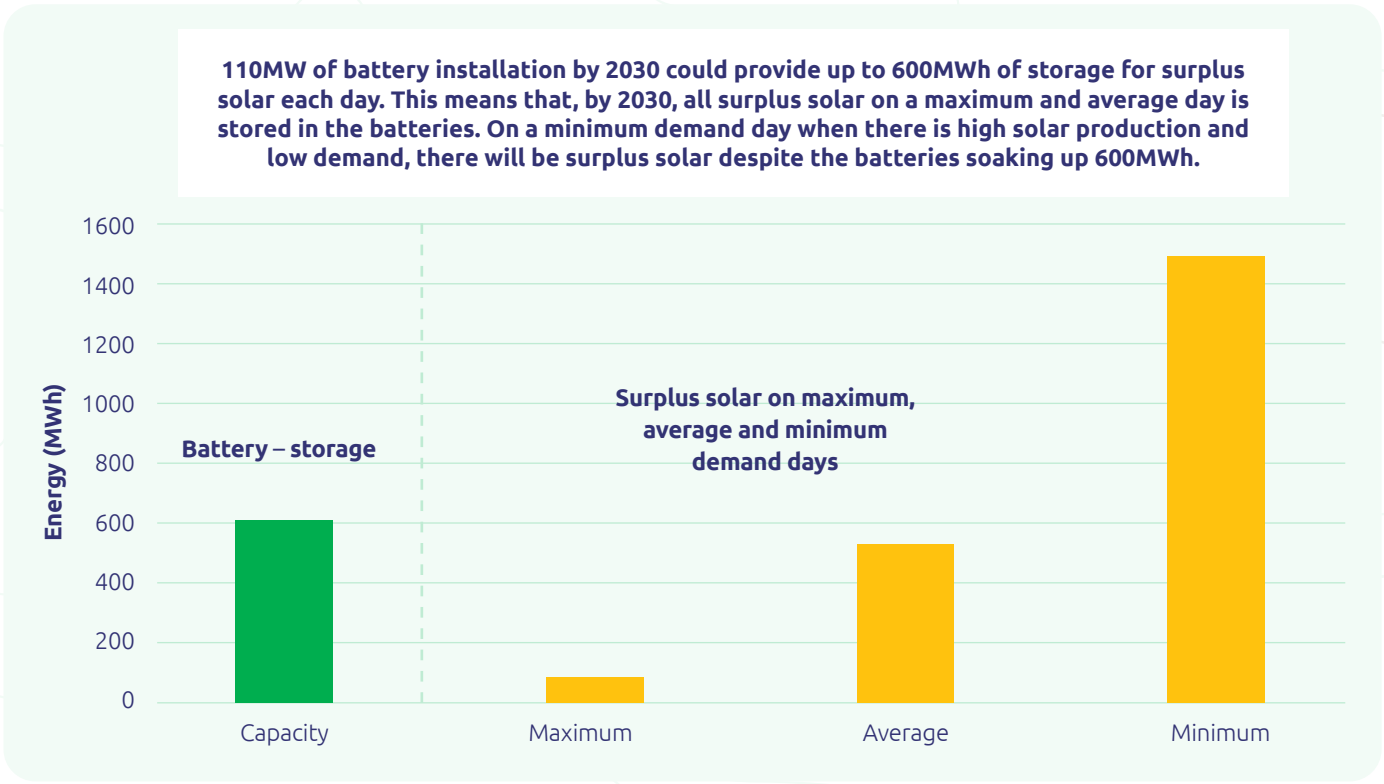


Figure 24: Generation profile over 24-hour period on an average day in 2030 (Seek Different)

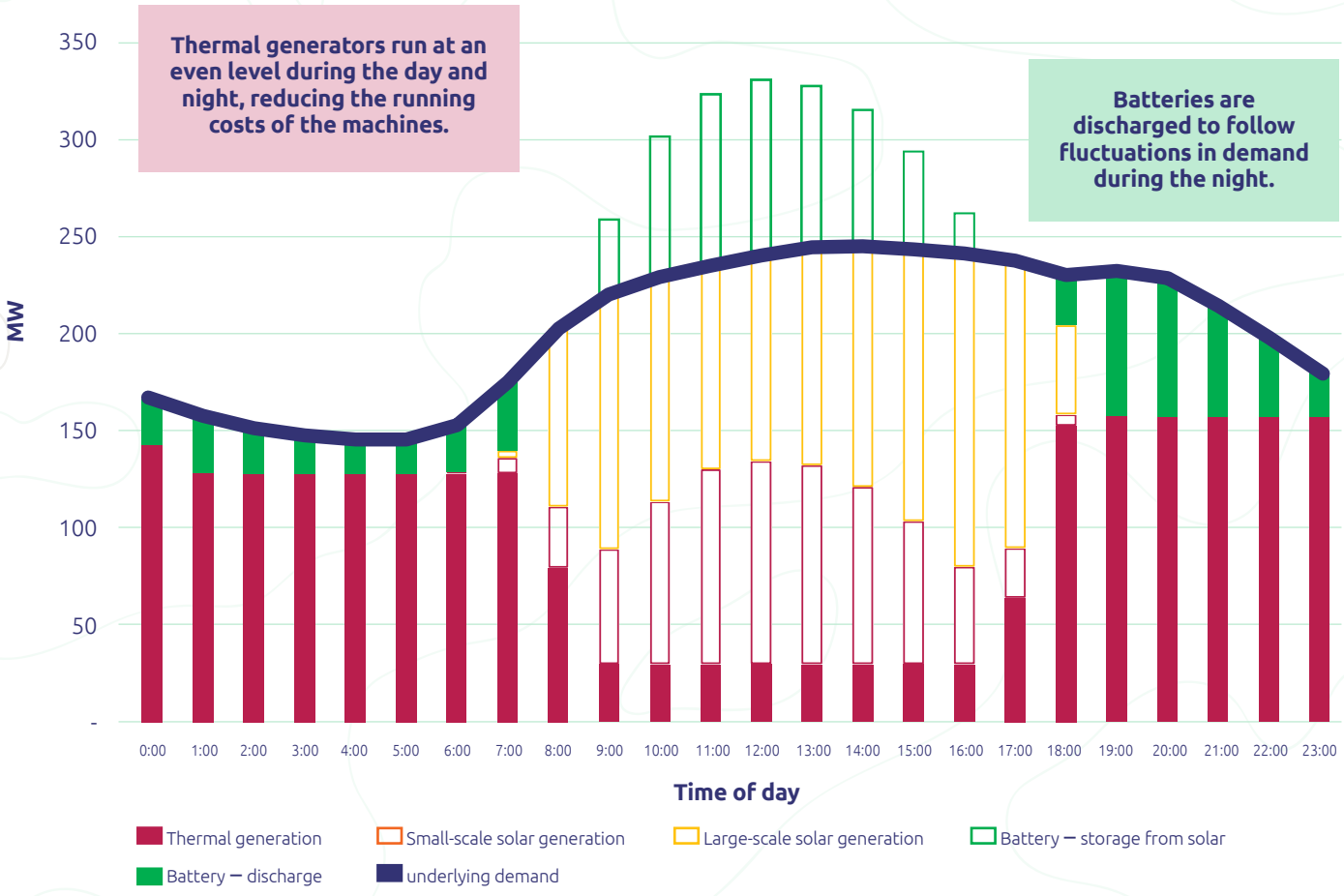




Figure 25: Changing thermal generation from 2020 to 2030 by location of generator

Almost 200MW of installed thermal generation capacity is expected to retire by 2030, to be replaced by only 80MW of new thermal generation capacity.

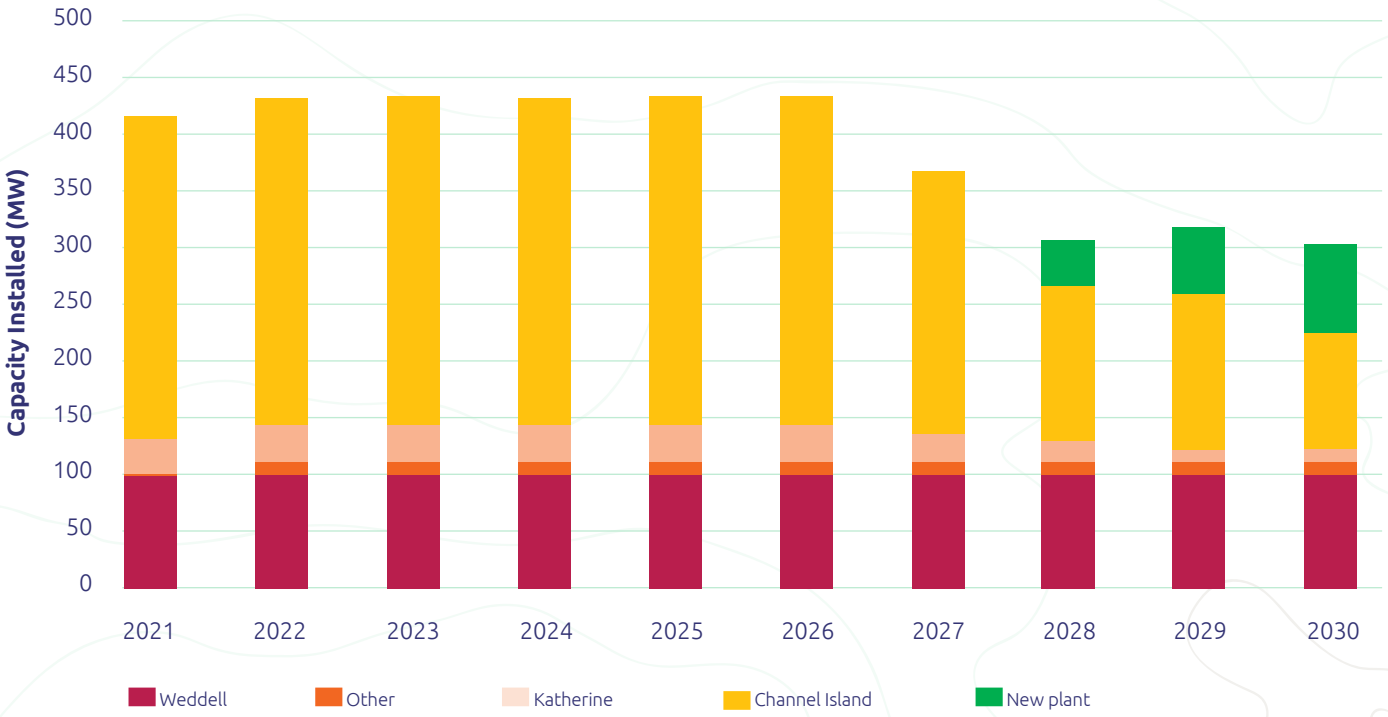
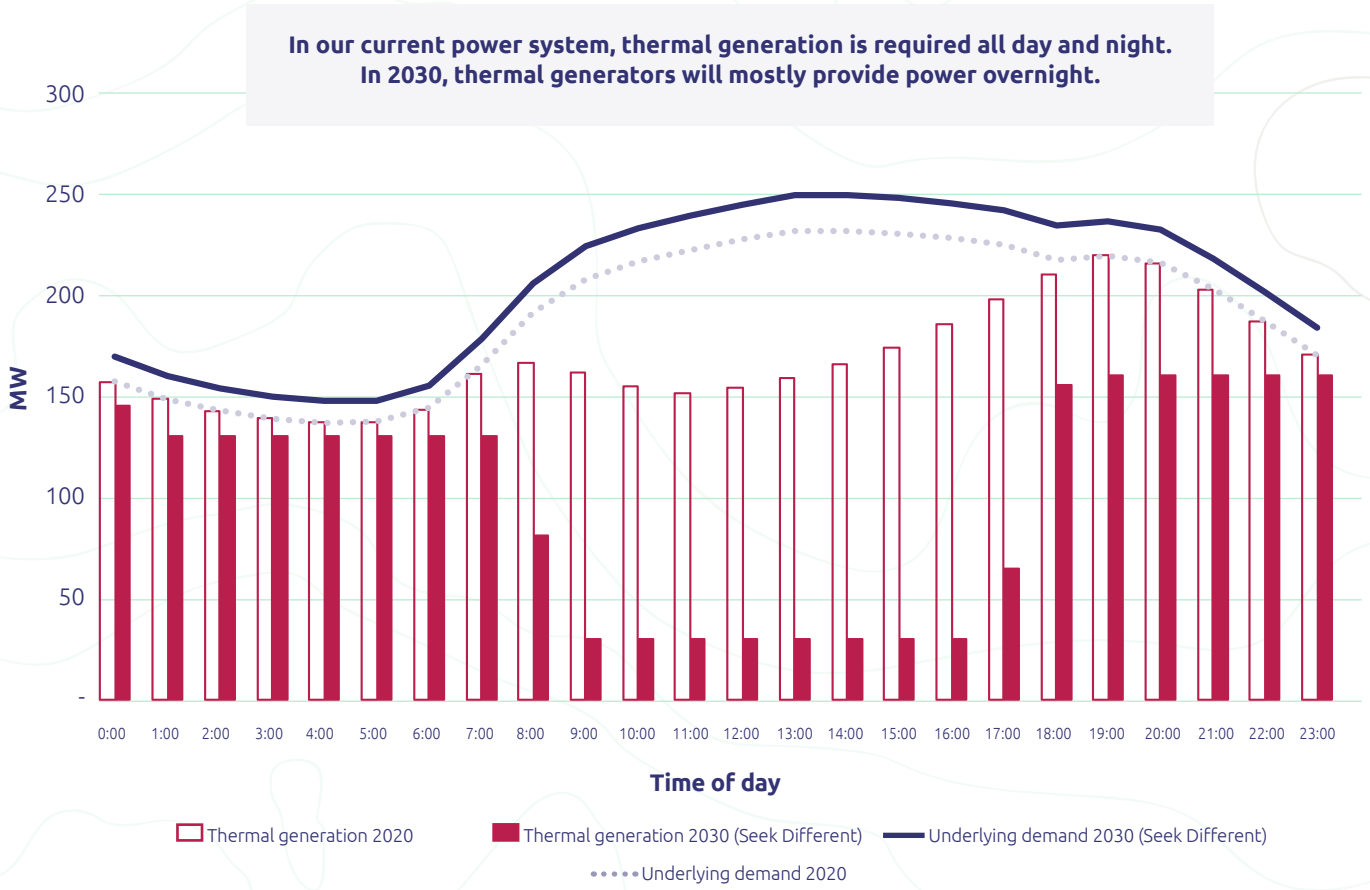


Figure 26: Changing role of thermal generation in the generation mix – comparing an average day in 2020 to an average day in 2030





3.4. Install 105MW of high spec security batteries

The power system is operated to keep frequency and voltages within specified limits to ensure the system is sufficiently robust to ride through a reasonable range of contingency events with little or no supply interruption. The power system services required to meet this objective are termed Essential System Services (ESS).

As noted in Section 2.4, power system services are currently provided by thermal generation. This is due to the dominant role of thermal generation in today's power system, and the inherent ability of heavy rotating technology to provide the services when required.

A major consideration is how the necessary level of ESS, to keep the system secure, can continue to be delivered in the transition to a 50% Renewable Energy Target by 2030. The rapid rise of small-scale solar is already posing security challenges for the system on minimum demand days by displacing these rotating machines.

The System Plan concludes that 3 high spec security batteries hold the key to providing sufficient system security services by 2030.

Section 5.2 demonstrates how batteries can provide necessary frequency services and potentially play a role in supporting system strength. Importantly, these batteries provide the system with more headroom to meet minimum demand days.

Timing and capacity of security batteries

The high spec security batteries focus solely on meeting security requirements, but may, in the future, also provide battery storage opportunities.

The System Plan identifies that three the batteries should be installed as follows.

- **2023**: The first security battery is already committed and will be commissioned by 2023. The business case for the first battery is premised on improving the efficiency of frequency control services. It is also expected that the battery is able to aid the immediate challenges with minimum demand. This is discussed further in Section 5.2.
- **2024**: The second security battery is not required for security until 2027 when frequency control services are required as thermal generation retires. However, as noted in Section 3.1, there is a financial case for bringing forward the timing of the battery to maximise renewable generation capacity on the DKTL.
- **2028**: The third security battery will be required to provide frequency services as the remaining thermal generators retire.

Each battery will have 35MW capacity, reflecting the required capacity to necessary levels of ESS at each stage.

Short-term management of minimum demand

Until the first security battery is commissioned in 2023, the system operator (Power and Water Corporation) will face increasing challenges as demand continues to fall on minimum demand days. Power and Water is proactively identifying mechanisms to ensure the system remains secure until the first battery is available for additional support.

3.5. Virtual Power Plants

A VPP provides the ability to communicate, aggregate and coordinate distributed devices and appliances of customers. This includes solar, batteries, airconditioners and electric vehicles.

Expert advice was sought as to how VPPs may provide support to achieve the 50% Renewable Energy Target.

Based on this, the System Plan identifies a need for the Darwin-Katherine electricity system to operate a 'fit for purpose' VPP by 2030.

With the expected doubling of small-scale solar by 2030, there is a need to expand the levers to manage small-scale solar while rewarding customers for providing services to the electricity system. The key benefits of a VPP are the ability to better manage small-scale solar.

VPPs also provide other benefits, such as:

- the ability to more reliably inject energy into the system to meet security and network needs
- helping to meet evening peak demand by coordinating the release of stored solar energy into the system when required
- providing the framework to unlock value for customers from their solar, battery and other devices such as electric vehicles.

The advice indicates there is a continuum of devices and services that could be provided by a VPP. The more complex a VPP, the more benefits are provided but costs also increase as outlined in Figure 27.

The System Plan posits that an incremental approach, providing opportunities to upscale and expand the VPP over time.

The success of a VPP largely lies in its implementation. There are five essential requirements of a VPP, covered in Figure 28.

1. Communication: the capability of customers' devices and appliances to communicate and respond to third party signals.
2. Monitor and Control: the ability of the system controller to adequately monitor the system and network, and communicate to devices when a need arises recognising the need to manage cybersecurity risks.
3. Compensation and Services: from the beneficiary of the service to the provider.
4. Governance: A framework which contains clear implementation rules, clearly defines the responsibilities of each party including, communicating service requirements, and explains how devices will be controlled.
5. Social License: Achieving informed consent from customers who provide tacit permission for a third party to control the device.

The System Plan sets out a timeline to initially get the essentials in place during 2021 to 2023, with the goal of operating a limited small scale VPP in 2024 to 2026, and an expansive VPP between 2027 and 2030.

Figure 27: Continuum of Virtual Power Plant services and devices

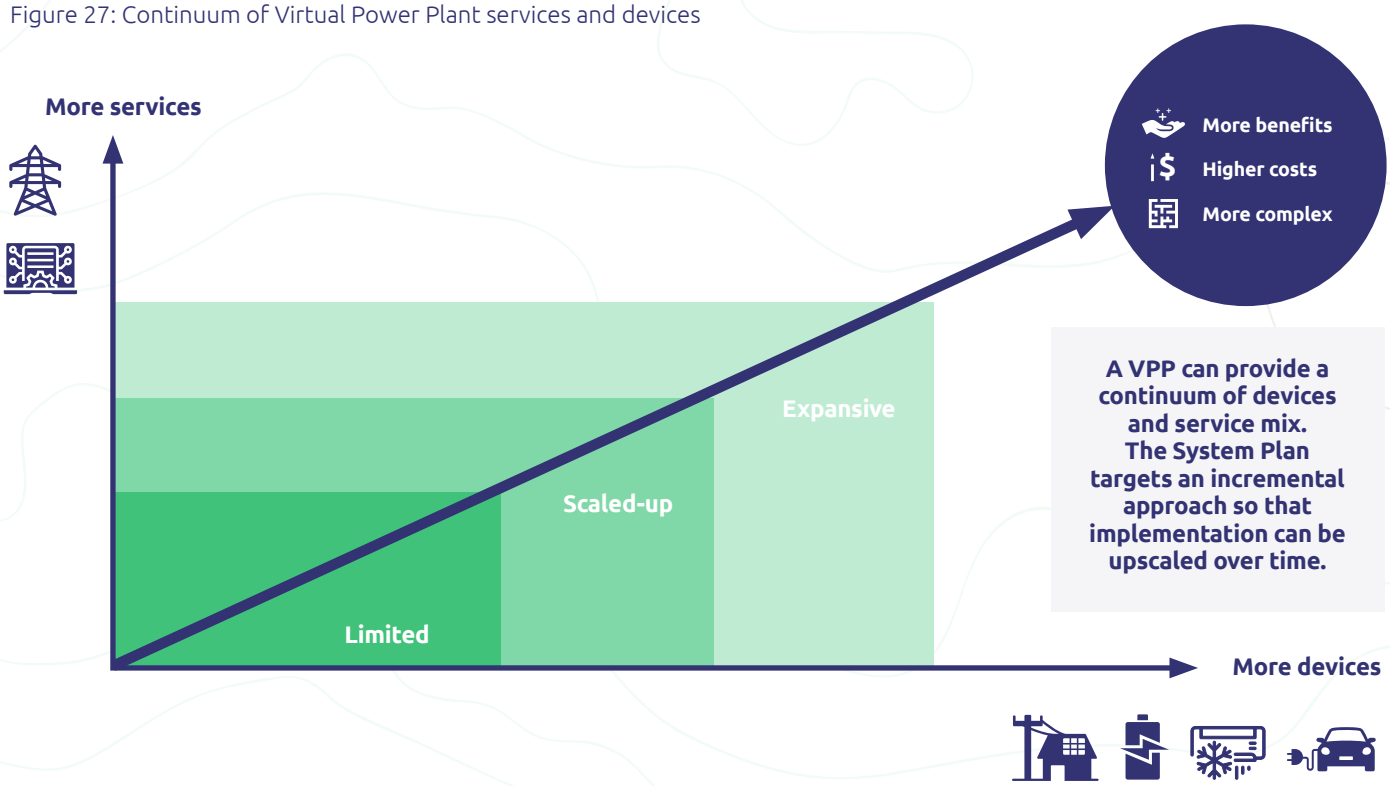
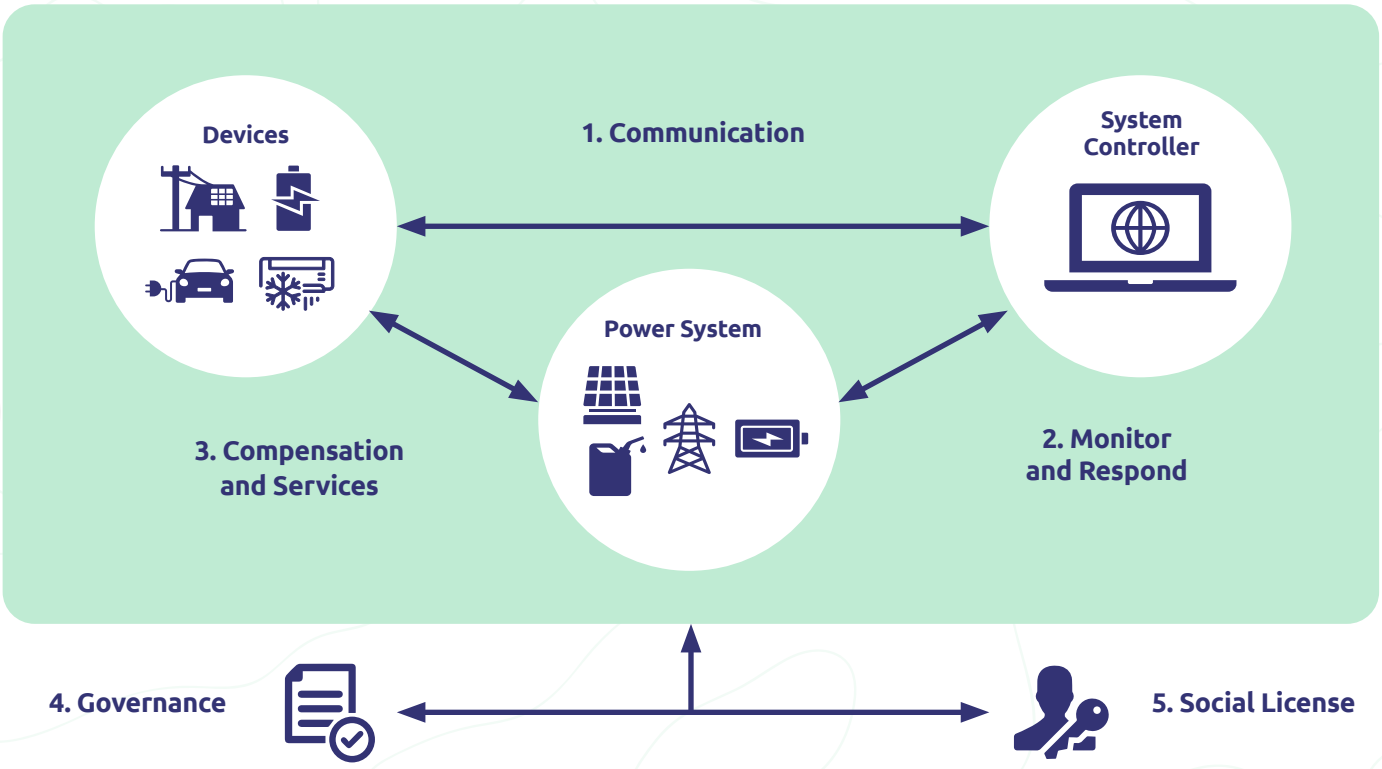


Figure 28: Five essential requirements for a Virtual Power Plant



3.6. Demand management initiatives

The Northern Territory is uniquely positioned to benefit from low-cost solar as underlying energy consumption occurs mostly during the day. This is due to heat and humidity driving higher airconditioning usage during the day.

As a result, more solar generated in the day can be utilised directly without the need for mass storage.

However, The System Plan analysis suggests there are further opportunities to shift demand into the middle of the day when there is surplus solar generation. The key opportunities are:

- management of airconditioning use in the middle of the day to cool the premises sufficiently to reduce airconditioner use in the evening;
- pricing structures that reward customers for dynamically using energyduring the day rather than in the evening and overnight;
- specific demand management initiatives for large customers to shift energy to the middle of the day, particularly on minimum demand days; and
- acceleration in uptake of electric vehicles and initiatives that encourage owners to charge during the middle of the day.

Analysis undertaken in the development of the System Plan indicates that about 20MW of consumption shifted from the evening to the day could reduce battery storage needs from 600MWh to about 450MWh. Surplus solar from the middle of the day can be used to meet demand at that time, rather than less efficiently through battery storage (refer Figure 29).This would reduce investment in battery storage by an estimated $4.5 million each year.

This underscores the significant role that electricity demand patterns can play in reducing electricity costs for all consumers. A range of levers is available to government to encourage more deliberate consumer choices including through price signals. These can be considered in parallel with technology solutions.

There is also opportunity to shape demand for new energy appliances, such as electric vehicles. The Territory Government is actively developing an electric vehicle strategy and implementation plan to promote the uptake of electric vehicles.

Analysis in the System Plan shows that a 10% uptake in electric vehicles by 2030 could result in an additional 15MW of energy in the middle of the day that could utilise surplus solar. This can be achieved if 50% of charging occurs between 10am and 4pm. Figure 30 shows how daytime charging can increase daytime use of energy.

Figure 29: Impact of 20MW of demand management (DM) on generation mix by 2030 for an average day (Central Scenario)

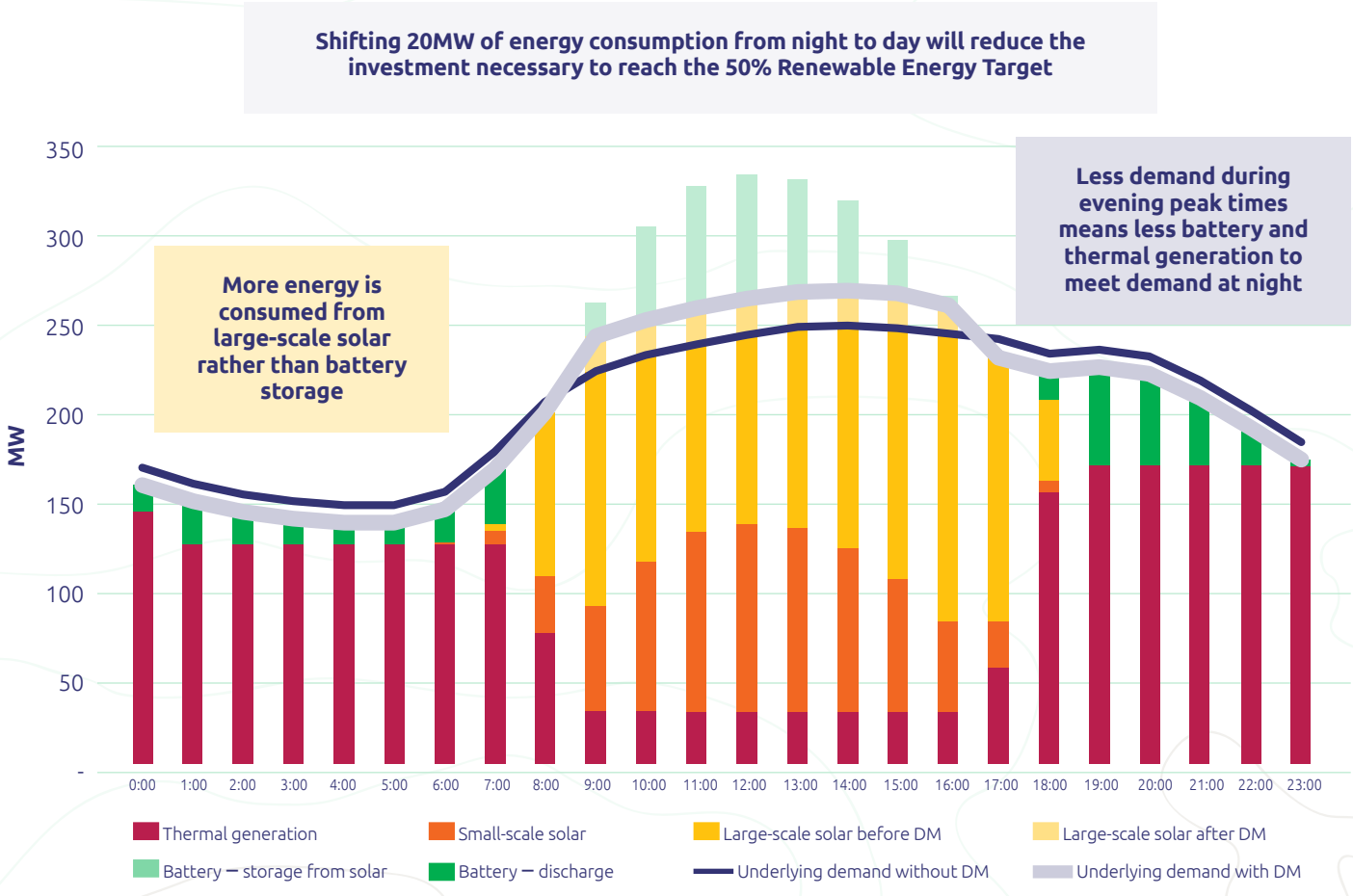
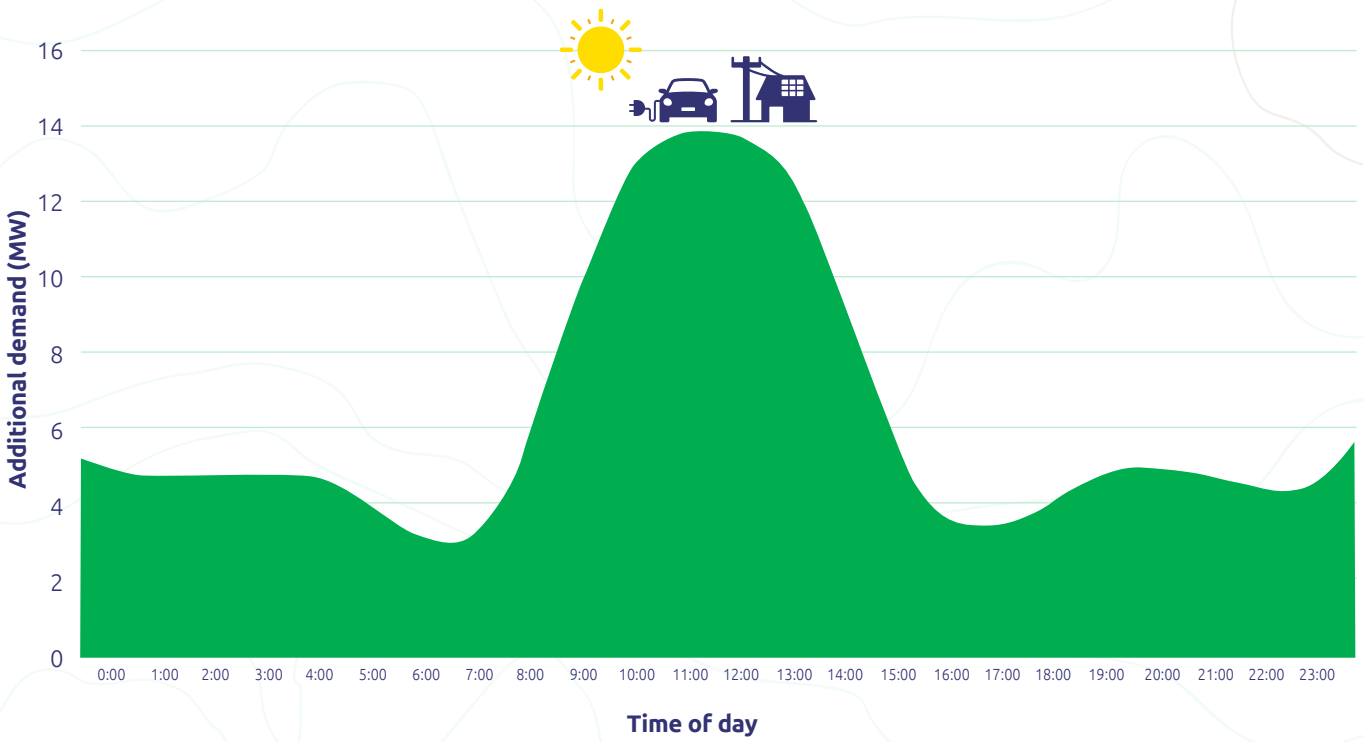


Figure 30: Electric Vehicles charging

About 15MW of energy could be delivered to electric vehicles in the middle of the day taking advantage of maximum solar output. This is based on 10% of vehicles being electric by 2030, and 50% of charging occurring between 10am and 4pm.





4. Bringing it together –a 10-year plan



The System Plan has carefully considered the complexities and challenges in implementing rapid change. The System Plan provides a 10-year pathway – sequencing focus areas into 3 stages. Timing is crucial – to maintain a strategic focus, the plan is proactive and seeks to stay ahead of the curve in transitioning to the 50% Renewable Energy Target.

The System Plan identifies the sequencing of focus areas into three stages – Ready (2021 to 2023), Set (2024-26) and Go (2027 to 2030).

Each stage is discussed below, together with analysis on how alternative scenarios may impact the pathway.



READY
2021-23

Ensuring the initial infrastructure and systems are in place to achieve the scale of the transition required over the next 10 years, while increasing the level of renewable energy.

SET
2024-26

Being 'ahead of the curve' before the expected retirement of thermal generation plants by increasing the scale of renewable energy in the system and securing the system.

GO
2027-30

Ramping up the scale of renewable energy and storage to enable retirement of older thermal generation plants.

Sequencing activities is the key to achieving the outcomes. Timing is crucial with careful planning required to ensure investment is efficient and capabilities are delivered. Consequences of potential delays must be recognised in order to adjust and respond.

Figure 31: Focus areas in the Ready stage of the Darwin-Katherine Electricity System Plan

READY

2021-23

FOCUS AREA 1

Install new solar and new Renewable Energy Hub

- Connect 25MW of behind-the-meter solar (2021-23)
- Connect 60MW of committed solar to DK Transmission Line (2021-23)
- Construct Renewable Energy Hub & transmission assets (2021-24)

FOCUS AREA 2

Install batteries to soak up and discharge solar

- Install 2MW of home and community batteries batteries (2021-23)

FOCUS AREA 3

Retire aged thermal and install new agile thermal generation

- Consider design specification of new agile thermal machines (2023)

FOCUS AREA 4

Install new high spec batteries to secure the system

- Manage minimum demand until first new battery System (2021-22)
- Install and operate first large battery system of 35MW (2023)

FOCUS AREA 5

Operate VPPs

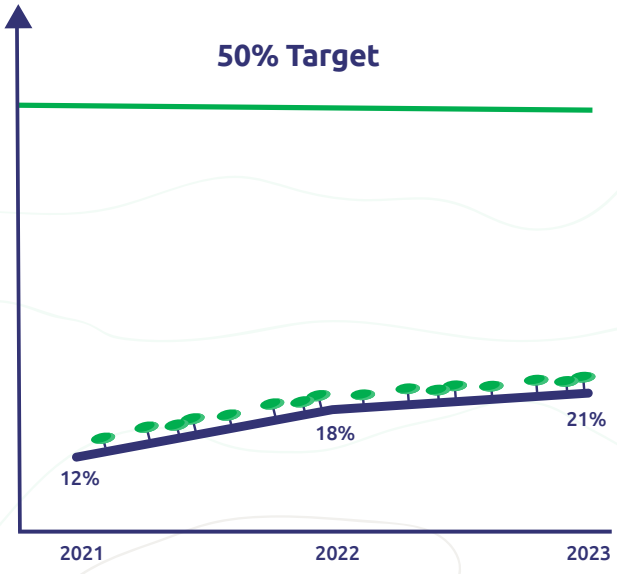
- Get VPP ready - identify options, and develop business cases (2022-23)

FOCUS AREA 6

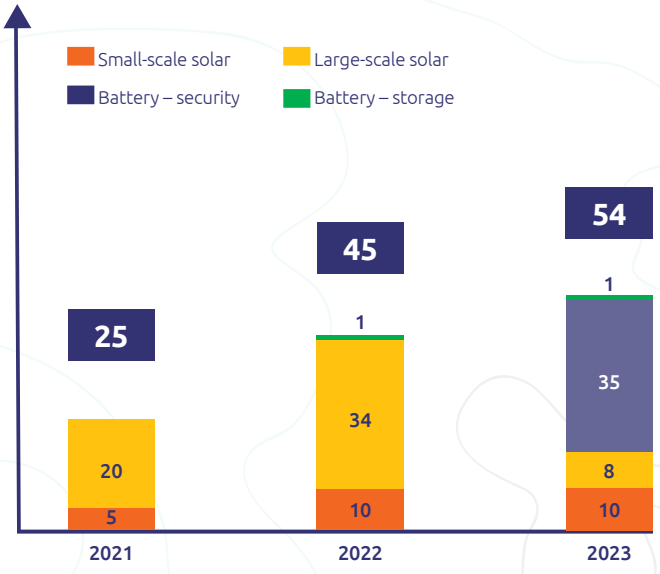
Incentivise demand management

- Consider pricing incentives to encourage energy usage during the day (2024-27)

Renewables as a proportion of underlying demand (%)



New capacity installed each year (MW)



4.1. Ready (2021-2023)

The Ready stage is about ensuring the infrastructure and systems are in place to achieve the scale of the transition required over the next 10 years. It is also about building capability by addressing immediate security issues while incrementally increasing renewables.

The Renewable Energy Hub is pivotal to unlocking large-scale solar by 2030. The construction of the hub is a significant project and will have a lead-time of at least 3 years. In the Ready stage, there is a need for the project to have achieved approvals and commenced construction. Steps include:

- identifying appropriate location and securing land
- resolving necessary approvals and checks including environmental and other regulatory processes
- determining the approach to finance and funding
- commencing site works and construction of connection assets and transmission infrastructure.

In the Ready stage, it is expected that 85MW of the 320MW solar needed by 2030 will be installed. 60MW of large-scale solar generation is expected to connect to the DKTL. A further 25MW of small-scale generation capacity is expected under the Seek Different scenario.

In this stage, there is no expected investment in large-scale storage. However, investment in household batteries is expected to start. Consideration could be given to pilots for community batteries in key parts of the network, but this would be on a smaller scale. About 2MW of home and community battery may be operational by the end of 2023.

The System Plan does not identify a need for thermal generation in Stage 1, but expects that, at a minimum, preparatory design work will be necessary ahead of the expected investment in new plant during 2027 to 2030. From a risk management perspective, acquisition of these small agile generators is likely to commence earlier.

Until 2023, the power system will need to manage minimum demand security risk to meet the challenges of more small-scale solar. This will be managed through demand management initiatives and other mechanisms currently available to the System Controller.

In 2023, the first high spec security battery is expected be operational and will deliver ESS. The battery will also assist in addressing the current challenges with system security on minimum demand days. This is an important test of the System Plan's vision to use batteries to secure the network in place of only thermal generation.

This stage is also about getting the system ready for a new VPP. This involves identifying options and developing the business case. Identifying the approach to commencing a platform in the next stage is critical.

By the end of the Ready stage, renewables will increase from 12% in 2021 to about 20% in 2023. Figure 31 identifies the key tasks based on the focus areas in this stage, and shows the expected annual progress to the renewable target and the approximate investments in new capacity.



Figure 32: Focus areas in the Set stage of the Darwin-Katherine Electricity System Plan

SET 2024-26

FOCUS AREA 1

Install solar and new Renewable Energy Hub to connect solar farms

- Expected 25MW of behind-the-meter solar (2024-26)
- Improve dispatchability on DK Tranmission Line (2024)
- Target 60MW+ connection in Renewable Energy Hub (2025-26)

FOCUS AREA 2

Install batteries to store and discharge solar

- Install 3MW of home and community batteries (2024-26)

FOCUS AREA 3

Retire aged thermal and install new agile thermal generation

Preparatory work for new agile thermal generation (2024-26)

FOCUS AREA 4

Install high spec batteries to secure the system

- Successful demonstration of Battery #1's performance
- Install and operate second large battery system of 35MW (2024)

FOCUS AREA 5

Operate VVPs

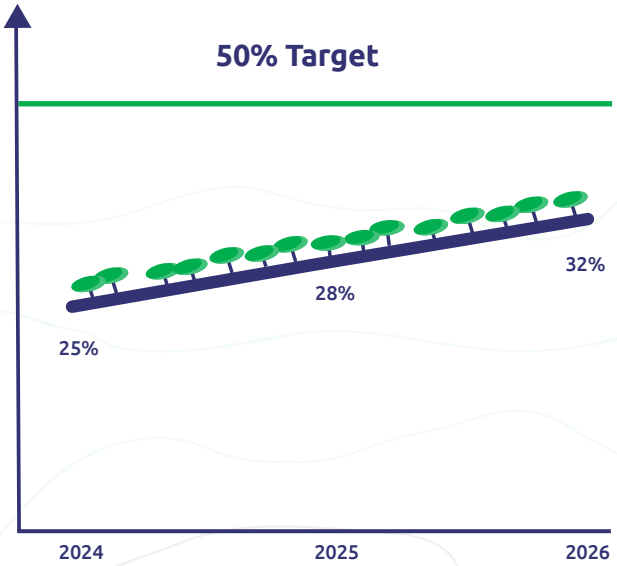
- Use limited VPP services on solar and batteries (2024-26)

FOCUS AREA 6

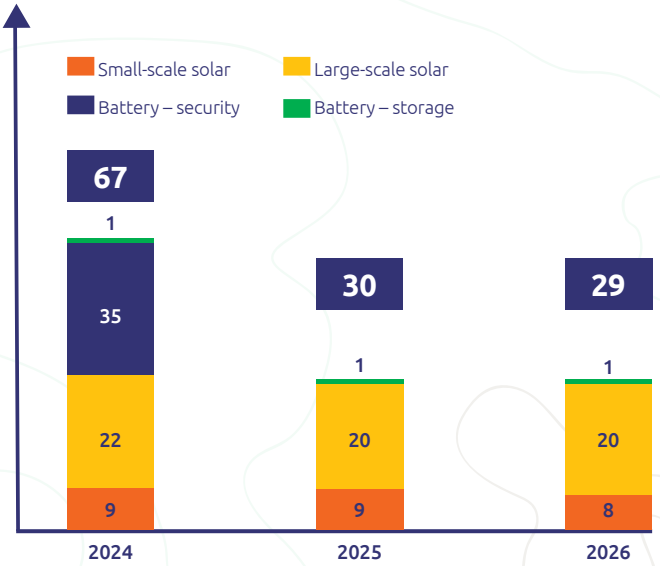
Incentivise demand management

- Consider pricing incentives to encourage energy in day (2024-26)

Renewables as a proportion of underlying demand (%)



New capacity installed each year (MW)



4.2. Set (2024-2026)

The Set stage is about being 'ahead of the curve' before the expected retirement of current thermal generation plant from 2027 onwards. This stage is about building momentum for renewable investment and operating VPPs at a limited scale.

About 85MW of solar generation is expected to be installed between 2024 and 2026. The Renewable Energy Hub is planned to be active from 2025, with new solar farm investors attracted to lower connection costs and the ability to maximise generation output. The System Plan estimates that about 60MW of large-scale solar will locate in the hub between 2025 and 2026. This will be accompanied by growth in small-scale solar of about 25MW.

The additional installation of solar between 2024 and 2027 means that most energy consumption in the day will be supplied by renewables by 2027.

By 2024, the performance of the first high spec battery should have been successfully demonstrated. In 2024, the second high spec battery will be commissioned in preparation to support system security as thermal generators commence retirement in the following stage. This second high spec battery will also improve system performance to allow for operation at lower loads and for a greater volume of solar energy to be delivered from the DKTL.

Battery storage is likely to remain limited to home installations and, potentially, some community batteries. Under the System Plan, battery storage would grow from 2MW in 2023 to about 5MW by 2026.

There is no identified need for new thermal generation in the Set stage. However, preparatory work on new thermal generators would be undertaken, including design, site works and, potentially, construction.

The VPP is expected to be operating in Set, but at a limited scale. This includes managing some small-scale solar and home batteries.

In this stage, demand management initiatives to shift load into the daytime period would start to demonstrate system benefits. This could include innovative pricing structures that reward customers for shifting load to the day.

Renewable energy would increase from about 21% in 2023 to 32% in 2026. This largely reflects the additional solar coming from the Renewable Energy Hub, together with small-scale solar growth. Battery storage has a small impact on increasing renewables in this stage.

Figure 32 identifies the key activities under each focus area for the Set stage, the progress toward the Renewable Energy Target, and the annual capacity installed of each new generation source.



Figure 33: Focus areas in the Go stage of the Darwin-Katherine Electricity System Plan

GO

2027-30

FOCUS AREA 1

Install solar and new Renewable Energy Hub to connect solar farms

- Plan for 30MW of behind-the-meter solar (2027-30)
- Target 120MW connection in Renewable Energy Hub (2027-30)

FOCUS AREA 2

Install batteries to store and discharge solar

- Install 4MW of home and community batteries (2027-30)
- Install 100MW of large-scale storage batteries (2027-30)

FOCUS AREA 3

Retire aged thermal and install new agile thermal generation

- 9 thermal generators at end of life (2027-30)
- Install 4 new 20MW thermal generators (2027-30)

FOCUS AREA 4

Install high spec batteries to secure the system

- Install and operate third large battery system of 35MW (2028)

FOCUS AREA 5

Operate VPPs

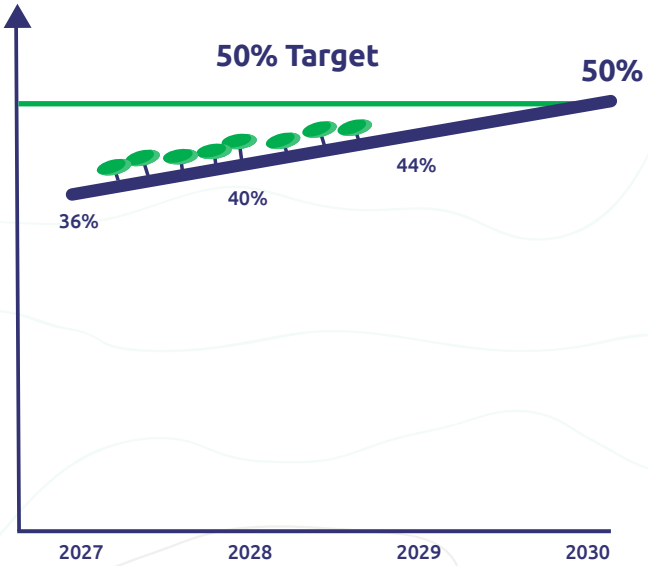
- Expand VPPs to accommodate broader set of devices (2027-30)

FOCUS AREA 6

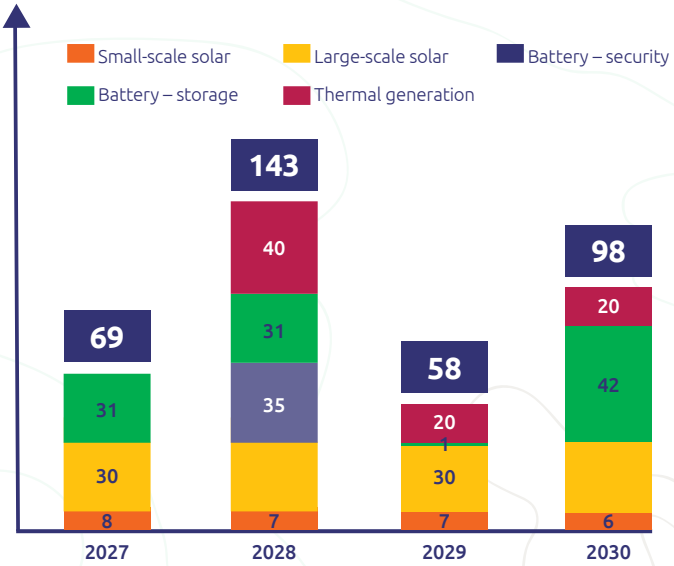
Incentivise demand management

- Initiatives to encourage EV charging in day (2027-30)

Renewables as a proportion of underlying demand (%)



New capacity installed each year (MW)



4.3. Go (2027-2030)

This stage is about ramping up renewable energy and securing the system as existing thermal generation is decommissioned.

In Go, about 150MW of new solar is installed, a significant ramp-up in capacity compared to the previous stages. About 120MW of solar farms connect to the Renewable Energy Hub. Small-scale solar continues to grow by 30MW over this period.

By 2030, most energy is delivered by solar generation during the day, except for the small amount of thermal generation required to keep the system secure.

Battery storage expands significantly over this period in line with the growth in solar. About 100MW of large-scale solar storage is installed in total, with the majority likely located in the Renewable Energy Hub. This allows large-scale solar investors to store surplus solar from the middle of the day, and discharge in the evening peak.

Home and community batteries will continue to be installed in this period, growing from 5MW in 2026 to 10MW in 2030. This may also help the network address local voltage issues, helping to defer capital expenditure and maximise solar generation potential for customers.

In this Go stage, almost 200MW of thermal generation (nine machines) are expected to be decommissioned. This is replaced with investment in 80MW of new thermal generation, potentially between 2028 and 2030 to meet overnight demand, but acknowledging that risk management requirements could warrant earlier commissioning, including before this stage.

In 2028, a third high spec battery will need to be installed to meet the frequency services requirements from the retiring generation.

At this point, there may be sufficient data to demonstrate whether batteries can be sufficient to secure the system on minimum demand days without the need for thermal generation, an important milestone test towards net-zero emissions.

In the Go stage, the VPP is upscaled with more customers aggregating solar, batteries and electrical equipment, such as electric vehicles. By 2030, the VPP will need to shift a small amount of small-scale solar generation, or inject load in the middle of the day on minimum demand days. The VPP may provide more services for system and network needs.

Demand management initiatives could open up opportunities to reduce investment needs in Go. The use of electric vehicles is likely to accelerate in this period, and it is imperative that there is a framework to encourage and allow customers to charge in the middle of the day. This will better utilise solar in the middle of the day, potentially lessening investment required for battery storage.

Figure 33 identifies the key activities in the Go stage, how this achieves the 50% Renewable Energy Target by 2030, and how much new capacity is installed each year of the final stage. Go is the beginning of the path towards net-zero emissions by 2050. This will be an ongoing and increasingly rapid growth in electrification and technical transition to a decarbonised electricity system.





4.4. Agility of the 10-year plan

While the System Plan has been based on the 'Seek Different' scenario, it recognises that any number of scenarios may eventuate over the next 10 years.

For this reason, the pathway must remain agile and robust in accommodating uncertainty. The System Plan examines how other scenarios may impact the pathway.

Uncertainty on the future also underscores the necessity to revisit the System Plan biennially and refocus activities as required.

From Little Things

Under this scenario, energy and demand growth is modest and small-scale renewables uptake is high.

The System Plan modelling shows that the essentials of the 10-year plan remain unchanged under this scenario. Almost 330MW of new solar is required to meet demand, compared to 320MW in the Seek Different Scenario.

About 140MW of new small-scale solar is installed, compared to 80MW under the Seek Different scenario. Only 190MW of large-scale solar is required, compared to 245MW under Seek Different. A Renewable Energy Hub remains the most cost-effective way of integrating large-scale solar into the system. There will be spare capacity in the hub in 2030 that will be filled as demand grows into the future.

Similarly, the same level of high spec batteries is required to secure the network, due to the rapid uptake of small-scale solar. However, the higher growth in small-scale solar means that VPPs will be required to play a role earlier. This is necessary to help capture surplus solar to discharge at night and manage system loads at minimum periods.

Battery storage remains crucial, and there may be a case for having a greater proportion of batteries in the home, compared to Seek Different, reflecting the higher penetration of small-scale solar.

Thermal generation would still be required as existing plant is retired but, due to lower peak demand, the capacity would be slightly lower at 60MW, compared to 80MW in Seek Different.

Sunshine for Sale

This scenario is based on a rapid expansion of demand in the Darwin-Katherine region from 2026, characterised by large industrial loads, increasing population and accelerated take up of electric vehicles.

Under Sunshine for Sale, solar capacity would need to increase by almost 50%, compared to the Seek Different scenario. Large solar would do the heavy lifting. The Renewable Energy Hub would still be delivered in 2025, but a second larger hub may be required by 2030 to reach 370MW of large-scale solar generation. At higher levels of demand, it may become economically viable to transport mass-scale renewables, including wind, potentially bringing forward investments not identified within the 10-year System Plan horizon, but that are part of the 1GW system covered in Section 5.4.

Battery storage will be scaled up with the increase in solar installed on the network, located at the Renewable Energy Hub rather than the home, reflecting the relatively high amount of large-scale solar.

New thermal generation capacity will also need to increase significantly to keep pace with higher evening demand.

The need for high spec security batteries is unchanged from Seek Different, as demand on a minimum day increases significantly.

While Sunshine for Sale increases the scale and timing of the 10-year plan, the focus areas and sequencing remain unchanged. Any additional system costs are absorbed by higher energy sales.

Figure 34 outlines the differences in outcomes under each alternative scenario, compared to the Seek Different scenario.

Figure 34: How scenarios change the focus areas

From Little Things



- More investment in small-scale solar
- Spare capacity on the Renewable Energy Hub that will be filled after 2030
- Virtual Power Plant implemented earlier to better manage small-scale solar
- Same capacity of battery security and thermal generation

Sunshine for Sale



- Booming demand means more large-scale solar required
- A second larger Renewable Energy Hub would need to be constructed before 2030
- Battery storage will need to be scaled up to capture surplus solar in the middle of the day.
- Thermal capacity will need to increase to meet higher evening demand

5. Outcomes and benefits

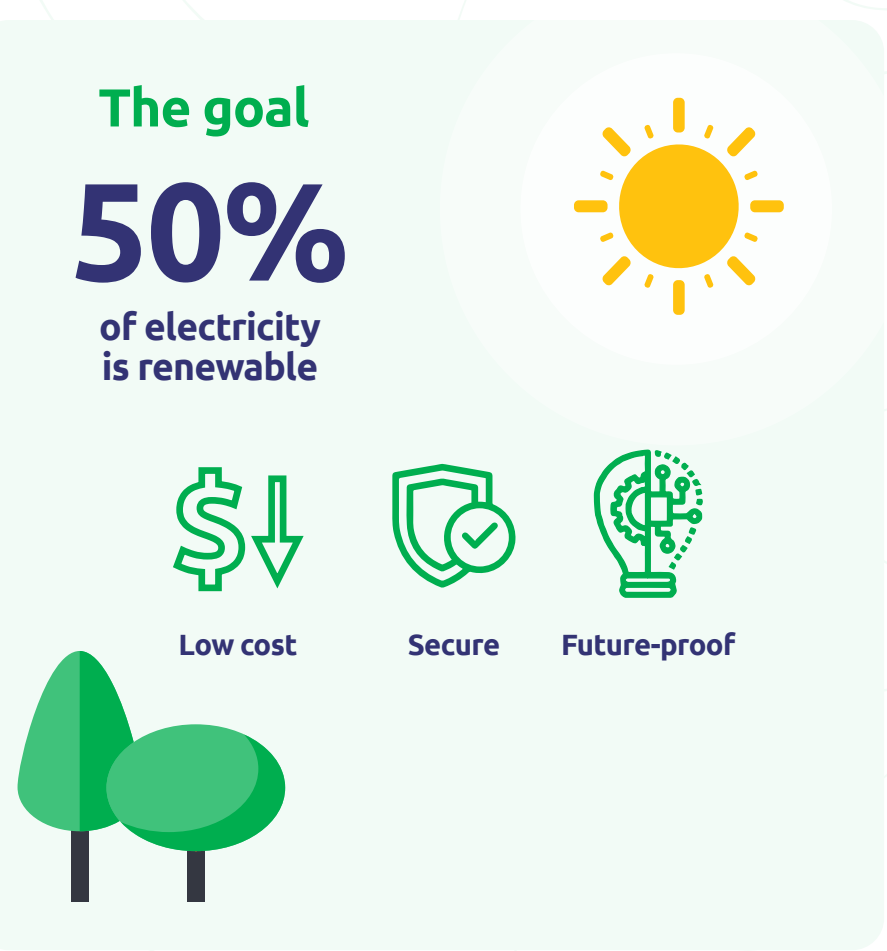


Gas Power Generation

This chapter demonstrates how the objectives of the System Plan are met in the 10-year pathway.

A 50% Renewable Energy Target is achievable while addressing power system challenges. It also shows that the target is lower cost than maintaining the current approach and continuing to reinvest in the generation technologies of today. Investment in the System Plan paves the way for a net-zero emissions economy by 2050.

Section 2.1 articulated the objectives of the Darwin-Katherine Electricity System Plan. This chapter demonstrates that the 50% Renewable Energy Target will be achieved under the investment pathway, while meeting the power system challenges at a lower cost than an alternative pathway, and in a manner that is compatible with the future. The key areas of uncertainty within the System Plan and strategies to manage and mitigate these risks are outlined.





5.1. Pathway will achieve 50% renewables

The modelling shows that the scale and timing of investments in the System Plan will meet the 50% Renewable Energy Target by 2030. Large-scale solar increasingly dominates the renewable mix to 2030, with battery storage contributing more in Stage Go (see Figure 35).

The modelling of alternative scenarios shows that the investment pathway is agile and can cater for major disruptors without compromise to the 50% Renewable Energy Target. Figure 36 demonstrates the different composition of renewables necessary to meet the target under each scenario, and the level of underlying energy.

Figure 35: Contribution of renewables by year to meet 50% Renewable Energy Target

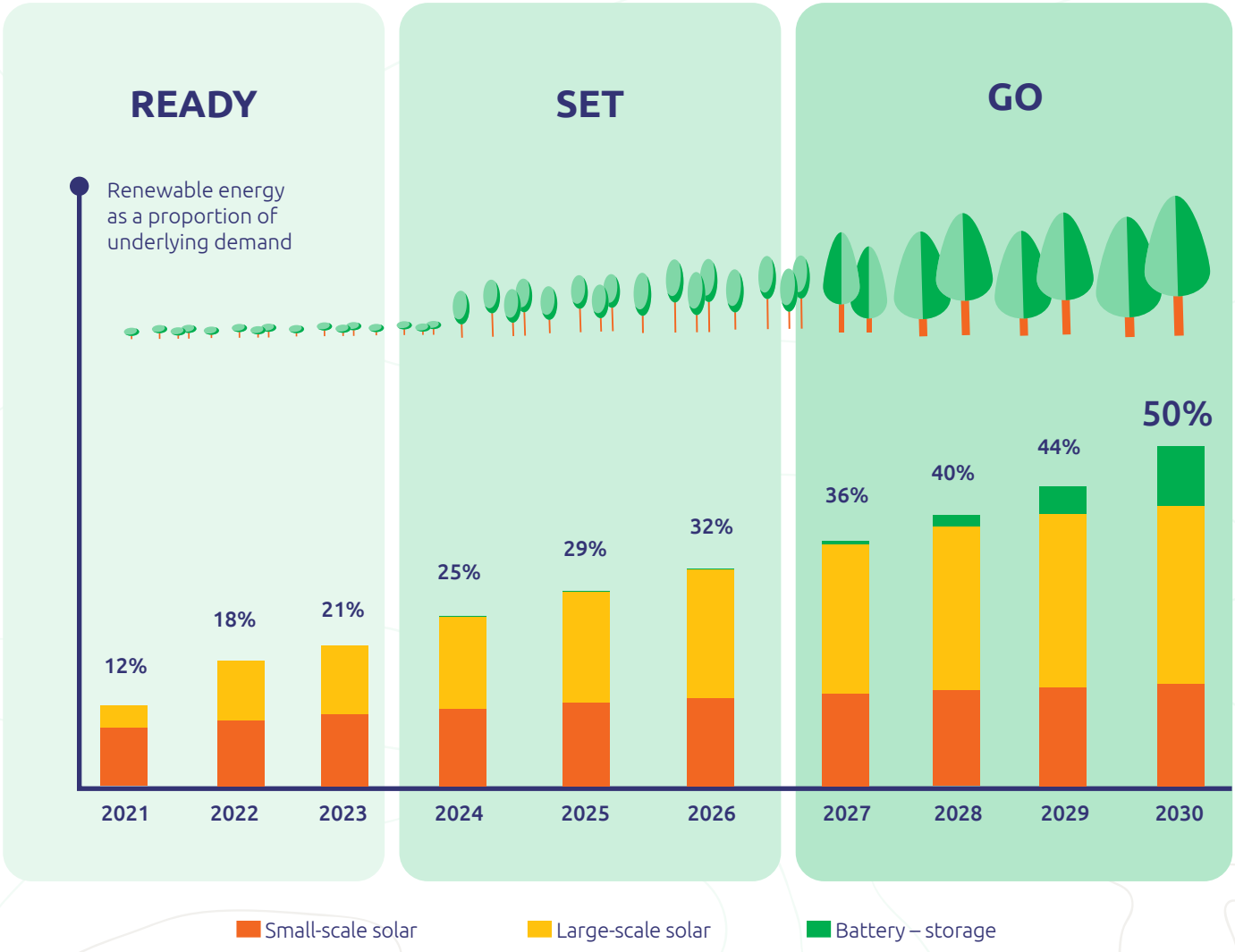
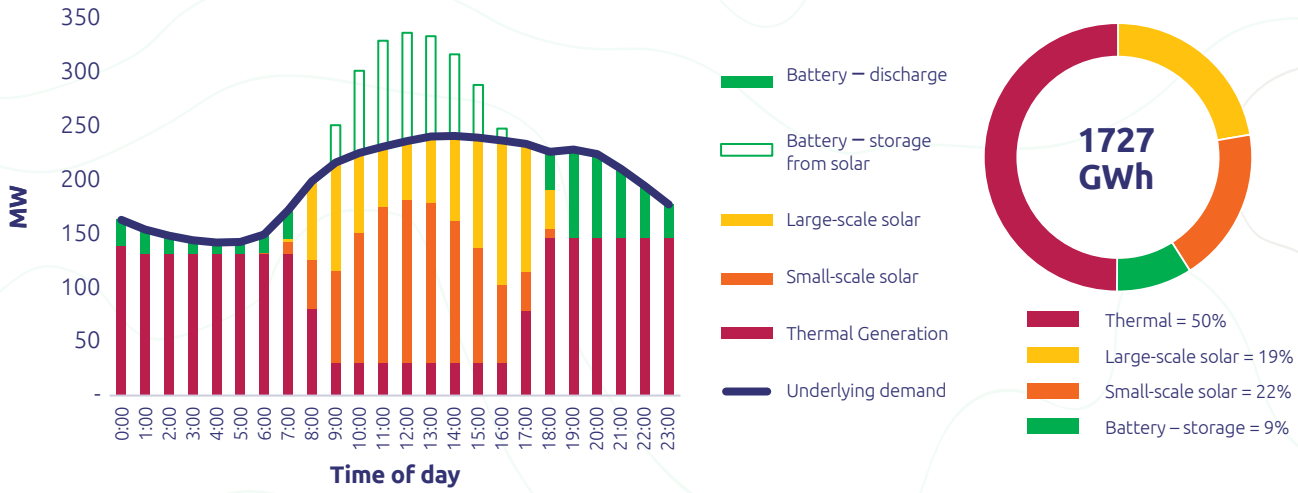
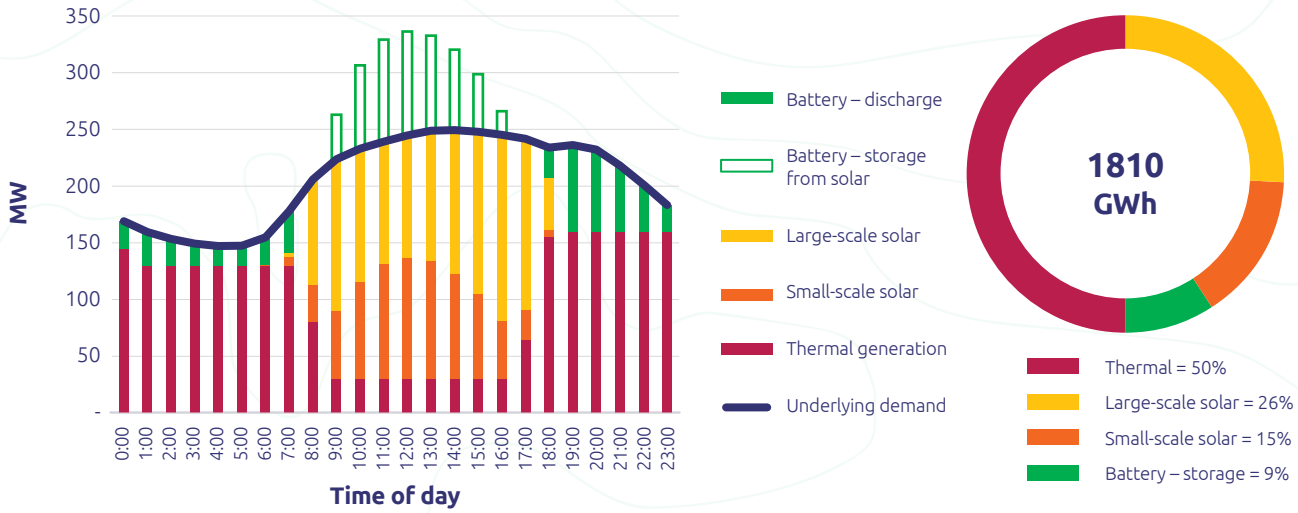


Figure 36: Renewable mix on an average day in 2030 (MW) and generation mix for annual consumption (GWh)

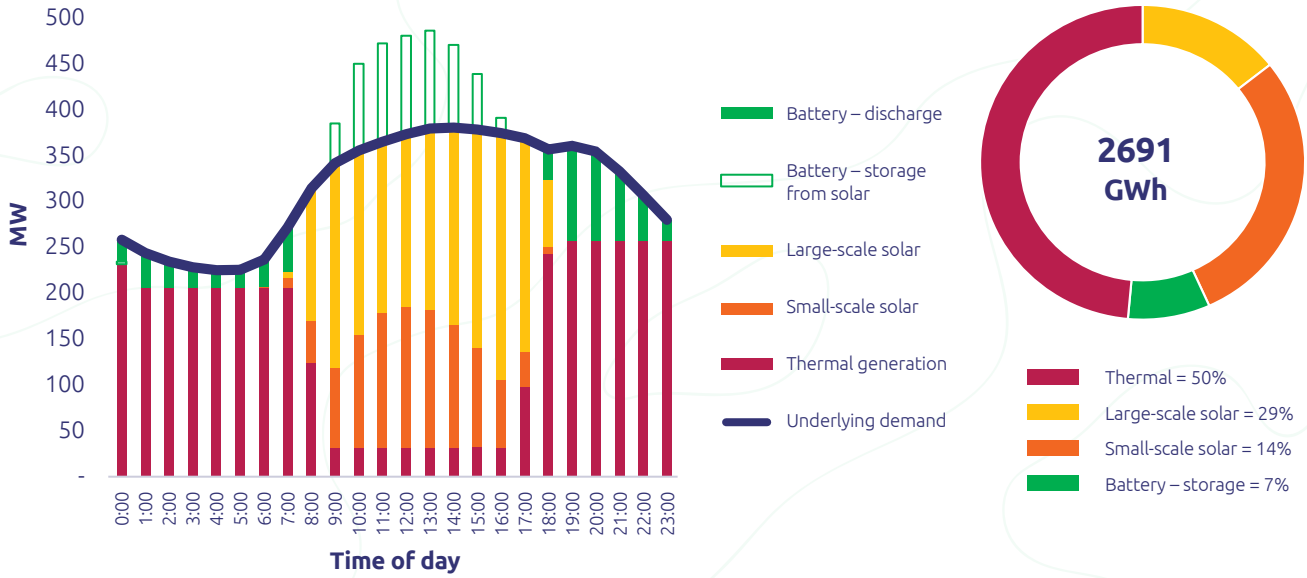
From Little Things



Seek Different



Sunshine for Sale



5.2. Meeting the power system challenges

Section 2.4 identified the key power system challenges from transitioning to a 50% Renewable Energy Target, including addressing night-time peak demand and system security. The System Plan analysis shows that the renewable mix in the Seek Different scenario would address each of these challenges as set out below.

Addressing peak demand challenge

Currently, the system is designed to provide sufficient generation to meet demand during peak periods under critical contingencies (for example, a major generator outage).

The System Plan examined two situations where the system will be most challenged - the evening peak in 2030, and an extreme monsoonal event in 2030.

Evening peak

The first test considered whether the generation mix in 2030 under the Seek Different scenario could meet demand in the evening and overnight. The key challenge would be solar energy displacing thermal generation, with the former only available in the day.

The modelling tested whether generation would be sufficient to meet expected peak demand in 2030. This occurs in the evening in the build-up period where airconditioning use is very high.

Under the Seek Different scenario, we expect the night-time peak demand to increase from 265MW to 285MW by 2030.

The modelling tested whether the level of thermal generation supported by battery storage capacity would meet this level of demand with the largest generator offline. This is termed an N-1 contingency.

The analysis confirmed that thermal generation would meet the peak demand, supplemented by about 25MW of battery storage capacity. This is less than a third of the total capacity of the battery storage.

Figure 37 shows how the generation mix in the night-time would meet the peak demand in 2030.

Monsoonal weather

The Darwin-Katherine regions experiences monsoons in the wet season. Monsoons reduce solar availability during the day due to extensive cloud cover and can continue for a number of days.

The challenge is then if underlying demand continues to be highest in the middle of the day. Further, batteries cannot be recharged by solar if the monsoon persists.

The modelling tested a worst case situation where only 10% of solar capacity is available on the maximum demand in the day in 2030. This is a conservative test as demand is expected to be lower on a cloudy day, and solar availability would be expected to be higher than 10% in such weather.

The analysis shows that thermal generation on the system in 2030 would provide most of the demand at the peak time, even with one major generator offline. The residual demand would be met by batteries charged by thermal generation overnight. This shows that less than a third of the available capacity of batteries would be sufficient to meet the demand. Figure 38 shows how demand could be met.

Figure 37: Sufficient generation to meet maximum demand

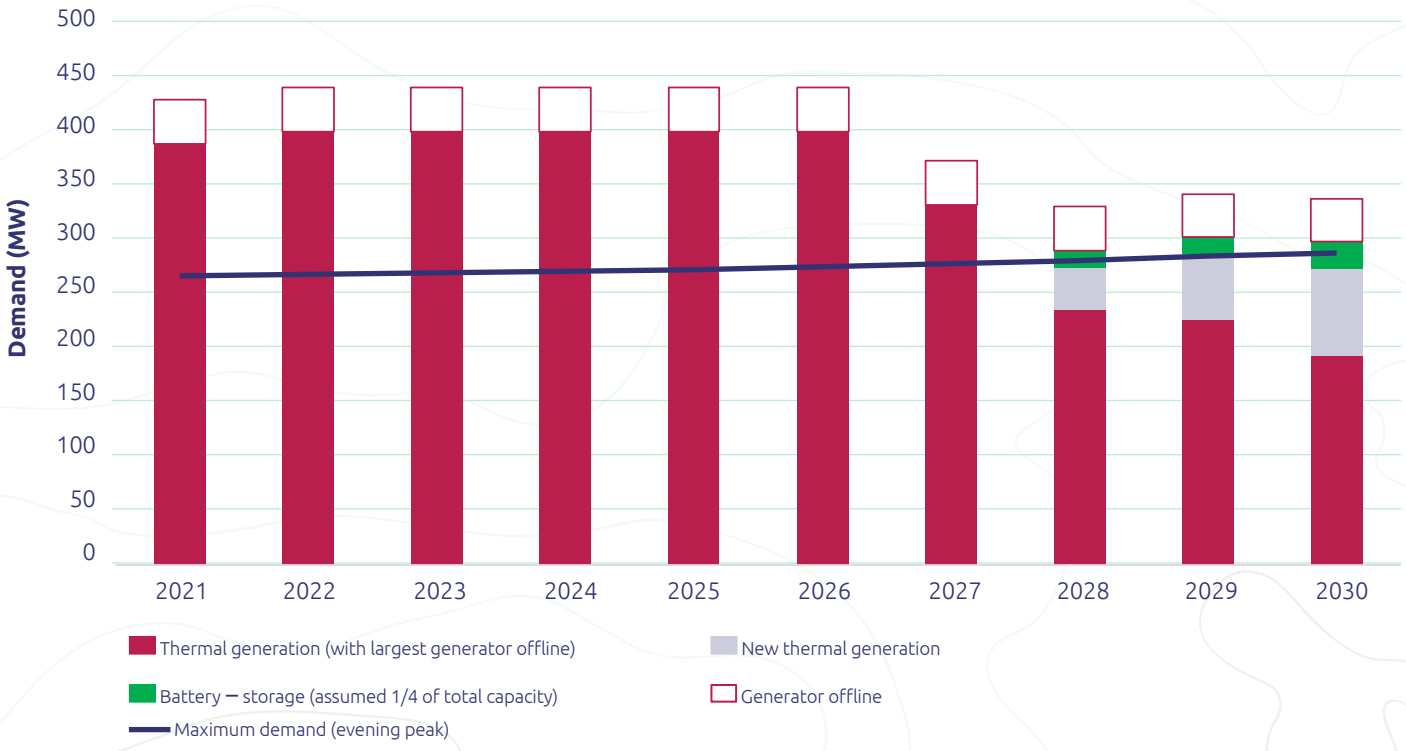
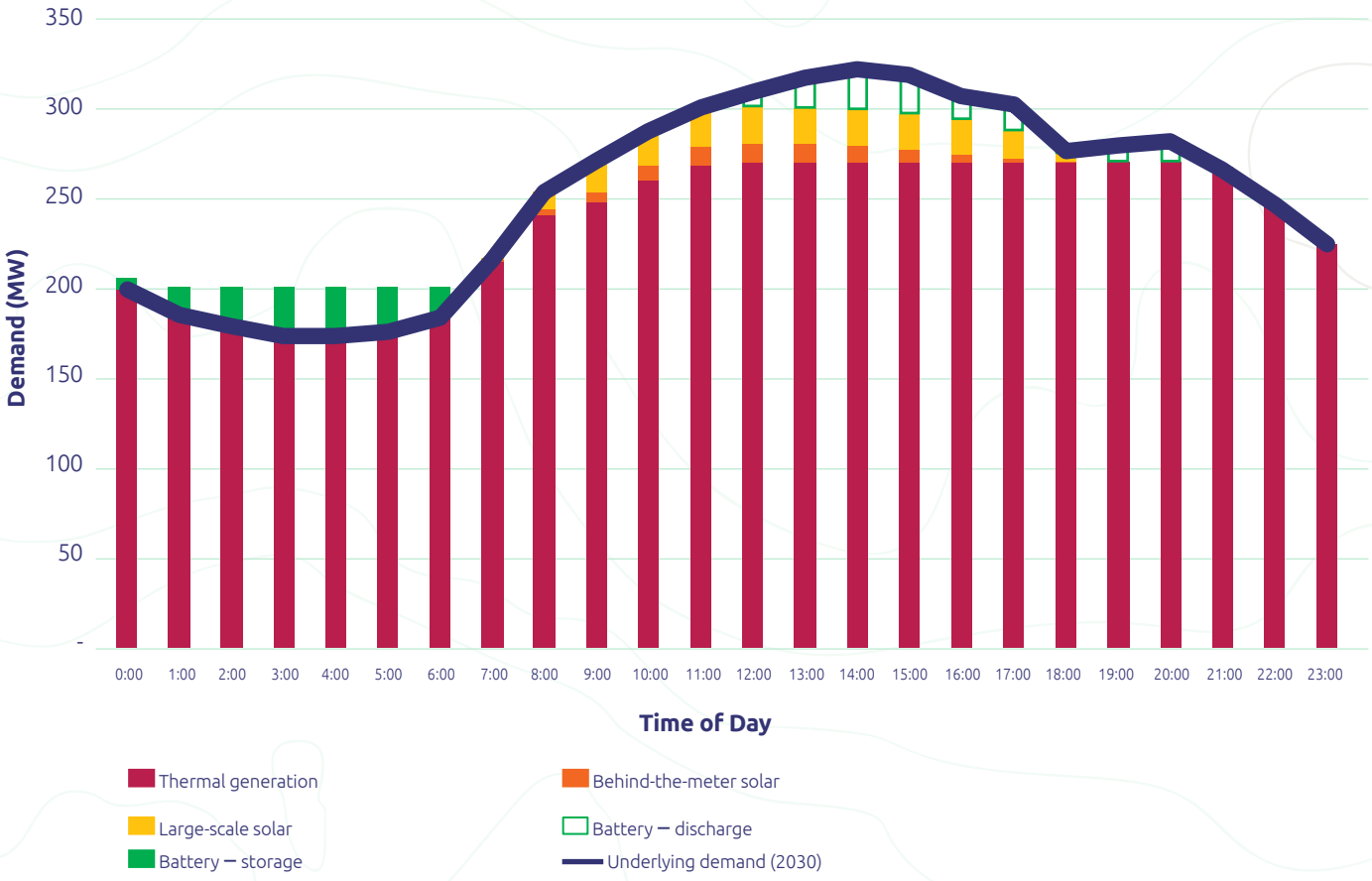


Figure 38: Sufficient generation to meet maximum demand on a monsoon day



Addressing security

The System Plan modelling also tested whether the proposed mix of high spec batteries and thermal generation would safeguard the security of the power system. This analysis covered frequency control, and other aspects of system strength.

Frequency

The most pressing security challenge facing the system is ensuring sufficient frequency control during a system disturbance. Currently, this is provided by heavy thermal plant and spinning reserves. The greatest challenge to this arrangement occurs on a minimum demand day when there is little requirement for thermal generation in the middle of the day.

In today's power system, about 60MW of thermal generation must be running to keep the network secure. The minimum load is forecast to fall to about 30MW in the Seek Different scenario.

The System Plan looks to batteries as the solution to lowering the minimum threshold to 30MW over the next decade. This is possibly due to the fast response times of batteries when a disturbance arises on the system.

Figure 39 shows that, until the first battery operating in 2023, the threshold load of thermal generation is about 60MW. The first high spec security battery from 2023 provides sufficient frequency services to potentially drop the threshold for thermal generation to 40MW. When the second battery is installed in 2024, the threshold may drop further to 30MW.

By 2030, the central scenario forecasts minimum demand to drop to 28MW, below the 30MW threshold. The third battery in 2028 could help drop the threshold even lower, potentially paving the way for a system that can operate without thermal generation.

The System Plan identifies that a more cautious approach is to rely on a VPP to help raise the minimum demand above the threshold by 2030. Together with demand management, this is expected to provide more than sufficient support to ensure the security of the network without relying solely on the capability of the third high spec battery.

The modelling also tests whether the system can provide contingency frequency control services. These are the services that arrest and halt frequency decline after a disturbance occurs on the system. The System Plan analysis (see Figure 40) shows that batteries provide a faster response , resulting in comparatively less need for a contingency frequency control service. Further, the first battery to be operating by 2023 will show that batteries are far more cost-effective than thermal machines at providing these services.



System strength

The analysis in the System Plan identifies a need to maintain system strength into the future. The biennial review and update of the System Plan will provide further analysis of technology and processes that can address the need as:

- the solar system technology that can operate at lower short circuit ratio limits than previous generations on PV systems come on line;
- more complex algorithms for fault detection in protection systems becomes available;
- the emerging capability of battery systems to replace system strength services are further explored.

Figure 39: Batteries reduce thermal generation required on minimum demand days (Seek Different)

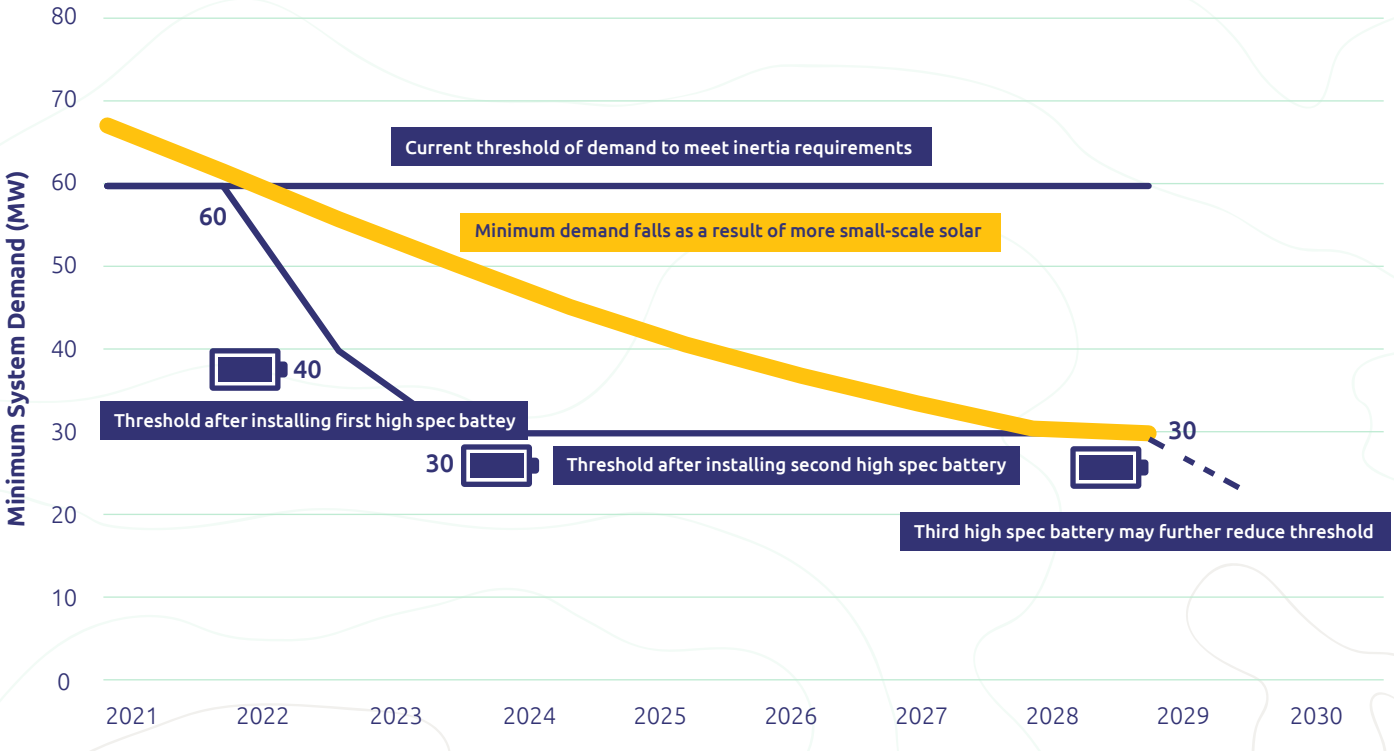
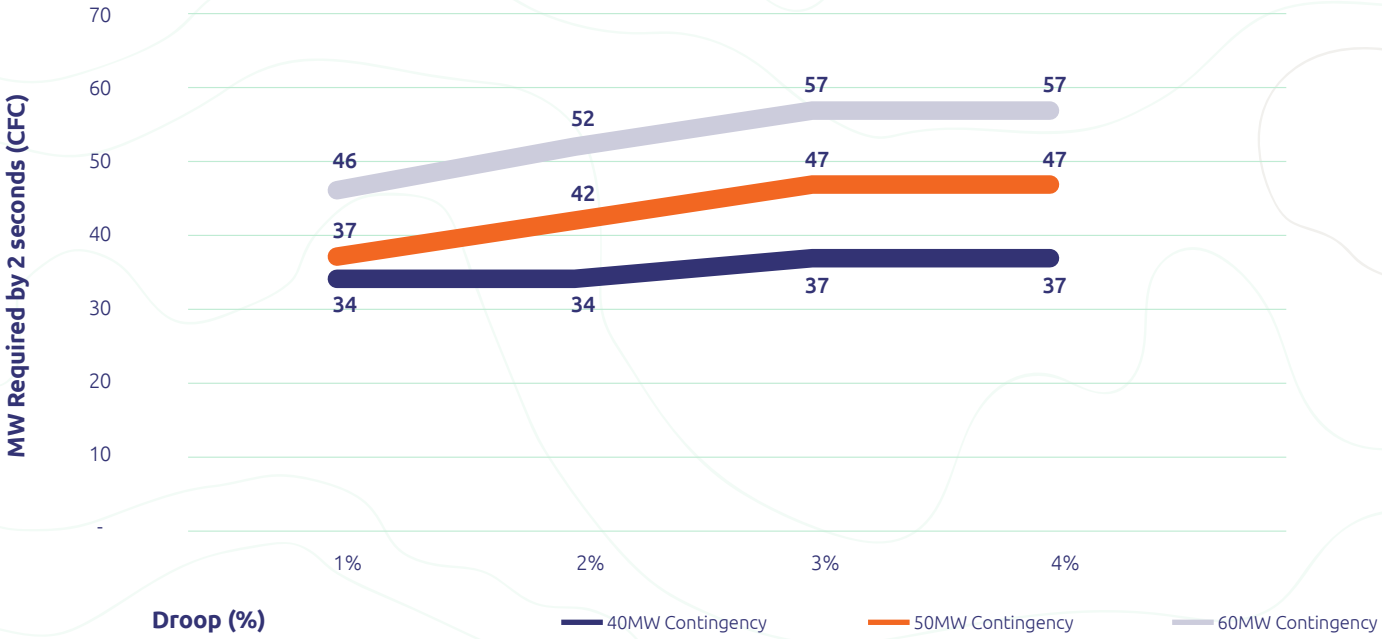


Figure 40: Contingency Frequency Control (CFC) service and response time (droop)

Figure 40 demonstrates that, with sufficient Rate of Change of Frequency services, faster responding technology, such as a high spec battery, provides benefits in reducing the quantity of services needed to keep the system stable.



5.3. Demonstrating lower costs

A key deliverable of the Renewable Energy Target is to use low-cost renewable resources to reduce the costs of electricity for customers. The question is whether the investments in the System Plan deliver more affordable electricity.

In addressing this question, the System Plan analysed the Business As Usual approach, which is to invest in replacing retiring generator capacity with modern day equivalent thermal machines.

The Business As Usual approach also assumes that small-scale generation continues to grow. However, large-scale solar generation would not grow past already committed solar generation. The Business As Usual approach results in 27per cent of energy being from renewable energy sources. As this would require additional investments in security to manage minimum system demand, the Business As Usual approach assumes that rotating technology is employed to provide security. The technology is synchronous condensers that are mechanically coupled to flywheels. These machines are connected to the system to provide frequency and voltage support services, without needing a minimum load to operate.

Figure 41 provides a comparison of the required investments under the status quo to the 50% Renewable Energy Target in the Seek Different scenario.

The analysis undertaken in the System Plan looks at both the generation and network costs. The costing has been undertaken in real terms (2020 dollars) to show the value in today's terms.

Generation costs

The cost analysis indicates that the generation costs would be about $3.5 million higher annually in net present value terms ($224 million) for a Business As Usual approach, compared with pursuing a 50% Renewable Energy Target ($191 million) with a Seek Different scenario.

The key reason is the higher cost of re-investing in thermal generation and synchronous condensers relative to solar and batteries. This also shows the importance of pursuing batteries to secure the network as an alternative to thermal generation.

Network costs

The revenue for Power and Water's regulated network services in Darwin-Katherine in 2020 was estimated as about $122 million.

The Seek Different scenario includes transmission works to connect the large-scale Renewable Energy Hub. This will result in an incremental cost of about some $3.5 million per annum, increasing revenue to $126 million a year. The Business As Usual approach largely uses the existing transmission network and does not result in any incremental network costs related to the power system.

Comparing the total costs

The annual total system savings from meeting the 50% Renewable Energy Target under the Seek Different scenario is estimated to be $30 million per year by 2030, compared to the Business As Usual approach. The analysis in the System Plan also shows that this is also a savings from today's system costs.

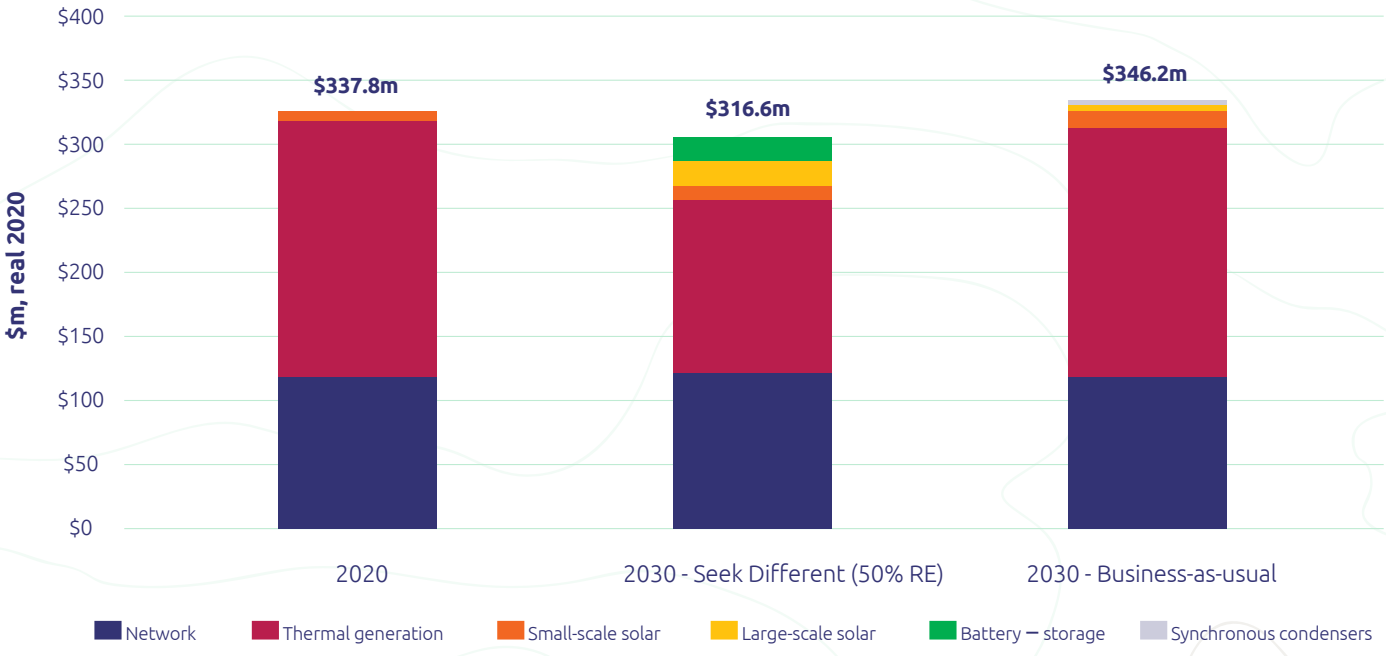
It is important to note that these figures are a 'point in time' estimate and are not a prediction of future electricity prices. Rather, the figures are intended to only be an indicative comparison of relative costs.

Figure 42 shows the breakdown of the annual costs in 2030 by generation or technology type, with the key difference being the relatively higher cost of thermal generation.

Figure 41: Comparing the investment mix of the 50% Renewable Energy Target to the Business As Usual scenario

	50per cent Renewable Target (Seek Different)	Business As Usual
	**240MW** Large-scale Solar **80MW** Small-scale solar	**60MW** Large scale Solar **105MW** Small scale solar
	**100MW** Large Battery Storage **10MW** Small Battery Storage	No investment in battery storage
	**80MW** New thermal generation	**200MW** New thermal generation
	**105MW** High Spec Security Batteries	No investment in high spec security batteries
	No investment in synchron condensers	**120MW** Synchronous condensers

Figure 42: Comparing the annual cost (generation and network) for today (2020), Seek Different 50% Renewable Energy Target (2030) and Business As Usual (2030)



These are the estimated annual costs of today's generation and network

These are the estimated annual costs from the investment capacity identified in the System Plan for Seek Different

These are the estimated annual costs from replacing retiring generation with similar technology together with small-scale solar

5.4. Emissions reductions and complementary benefits

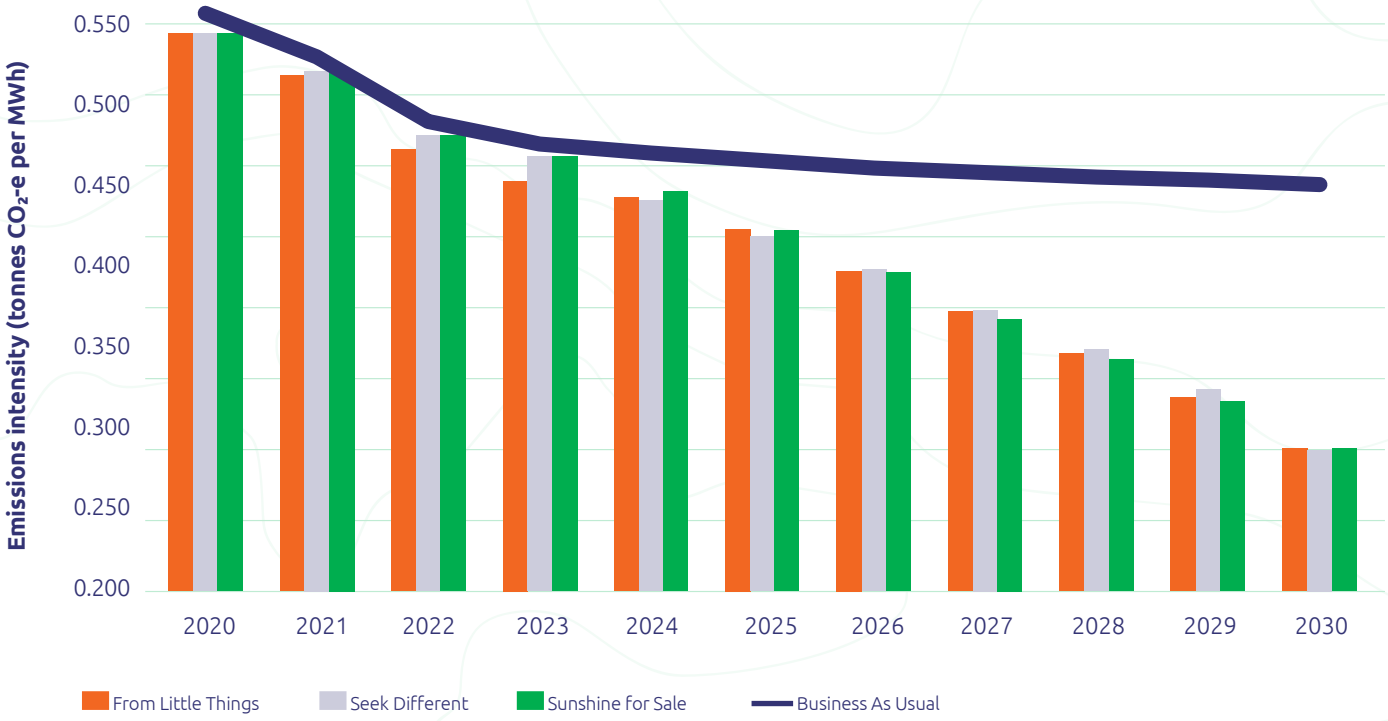
The analysis in the System Plan demonstrates that emissions would be significantly lower per unit of electricity supply under the 50% Renewable Energy Target.

Figure 43 shows that emission reductions through to 2030 are similar for each scenario in the System Plan and compares this to Business As Usual, where emissions remain almost constant over the same period.

There are other benefits of a cleaner energy system that we have not expressly considered.

- **Environmental benefits:** As noted in section 1.3, there is a clear imperative for the Darwin-Katherine region to be part of a global response to reduce emissions, due to the impact of carbon on our climate system.
- **Greening supply chains:** Overseas markets are likely to incorporate an import tariff on carbon-intense goods. For this reason, the Territory can show that goods have been produced using a cleaner energy system. The Territory is currently considering an Environmental, Social and Governance (ESG) framework to guide investors' understanding of our position on these metrics.

Figure 43: Emissions reductions (tonnes CO_2-e/MWh)



5.5. Future-proofing to 2050

The System Plan is focused on a 10 year planning horizon to provide an indication of the technology and investment that is required to meet the 50% Renewable Energy Target. The mix of solutions has an eye on the future – ensuring that the power system is set up to deliver net-zero emissions, in a vastly expanded economy by 2050.

There are many aspects of the System Plan that set the Darwin-Katherine Electricity System up for success in the future.

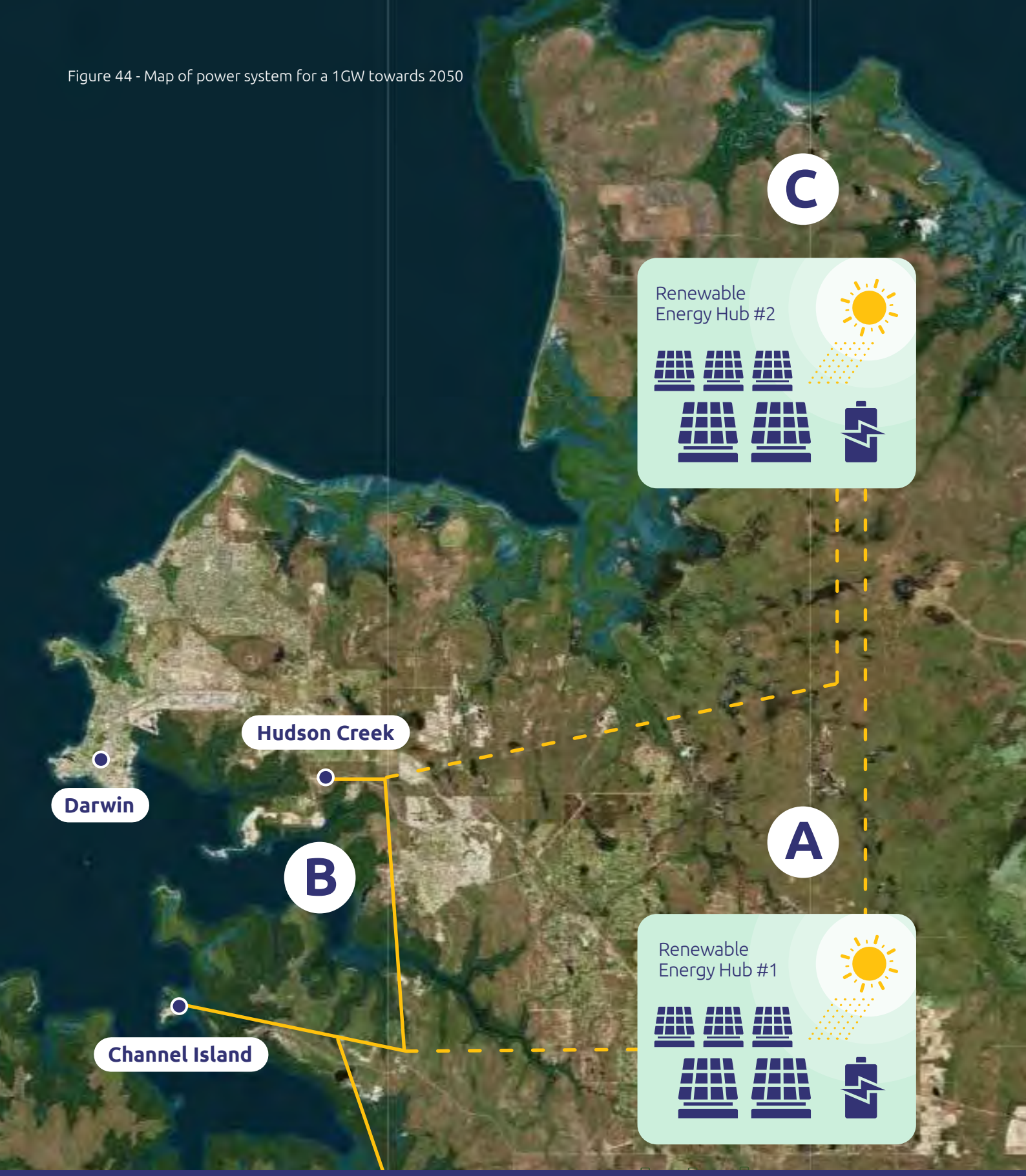
Transition from rotating machines to batteries

Thermal rotating machines have been the foundation of power system security for over a century and a full transition to renewable energy will require a shift in thinking.

New inverter technology used with a battery and solar generation offers a new paradigm for power system operation, with greater opportunities to better manage the system beyond what is possible with rotating machines alone. The transition towards a 50% Renewable Energy Target requires these technologies to successfully work together.

The System Plan contemplates batteries as a viable substitute for thermal generation. While there is much to test and verify, batteries are proving to have the intrinsic qualities required for power system security. With prices expected to fall in the future, batteries can offer value given the diversity of services they are able to offer including storage of solar and essential system services.

Figure 44 - Map of power system for a 1GW towards 2050



Existing transmission line

New transmission line

A By 2030, the plan is to replace thermal generation with solar/storage with a 180MW Renewable Energy Hub.

B Toward 2050, demand could reach 1GW with a booming economy including advanced manufacturing and data centres.

C The long-term vision is to build a second Renewable Energy Hub north of Darwin that would accomondate 300MW of solar and also storage. The hubs could also connect to high capacity transmission lines from southern regions.

Transition to new sources of renewables

Solar will continue to drive further acceleration of renewables post-2030 but there is also a need to think more creatively about where and how more renewables can be connected to the power system.

For instance, in a vastly expanded economy, there may be economies of scale in transporting solar or wind at mass scale from low cost and highly efficient sources outside the Darwin-Katherine region. The System Plan leaves open these possibilities, in particular the prospect of new Renewable Energy Hubs that can form an interconnection point to transport renewable energy at scale.

The System Plan also considers how emerging renewables, such as renewable hydrogen, can continue to drive the system's transition to net-zero emissions. For example, the plan identifies the need for new agile thermal machines that can utilise renewable hydrogen as a fuel source.

This means that the proposed investments are not fully captive to emissions technologies but can be converted to mostly renewables when the technology becomes viable. This provides for an effective transition to net-zero emissions in the future while maintaining the value of assets over their lifetime.

This also provides good opportunities for the Northern Territory to showcase locally sourced renewable hydrogen as a viable renewable energy source within its own power system. This will be the key to establishing cleaner supply chains in order to unlock export markets for destinations that will rely on renewable hydrogen to meet emissions targets.

Setting up the power system for 1GW

The System Plan also provides an outline towards delivering 1GW of electricity demand required to achieve the government's vision of a vastly expanded economy.

This is four times the level of demand today, and reflects the region's prospects of expanding industries, bringing with it population growth and economic diversification.

The System Plan looks to the Renewable Energy Hub as the primary vehicle to meet the 50% Renewable Energy Target by 2030. Under the Sunshine for Sale scenario, more Renewable Energy Hubs of a larger scale may be needed to efficiently connect large-scale solar over time.

The 1GW vision is beyond the demand forecast in the Sunshine for Sale scenario. This future will require the establishment of multiple Renewable Energy Hubs. The hubs can be ideal locations for the connection of inter-regional transmission connections to hyper-scale renewable developments in the more southern regions of the Territory as demand grows.

System development also enables expansion of existing and establishment of new industries based around access to abundant renewable energy, including renewable hydrogen production for export, advanced manufacturing opportunities and large-scale data centres.

The system will also provide new infrastructure to areas that are not currently as well-serviced across the Darwin-Katherine region.

Sensible staging of the system development means the decisions and investments made today can be made in a 'least regrets' context. They maximise the opportunity for investments to provide value into the future.

For example, the establishment of a Renewable Energy Hub towards the 50% Renewable Energy Target is also the first step in the development of a 1GW power system. The System Plan provides flexibility to scale up the supply of renewables as demand grows. Figure 44 shows a map of what the 1GW power system could look like.

5.6. Risks and mitigation

The System Plan is cautiously ambitious. It recognises that there are emerging technologies, which could provide more technical and cost-effective options to reach the 50% Renewable Energy Target and ensures these remain in play.

The System Plan has flexibility to pivot in the event technologies do not fulfil expected capabilities. Key risks and potential mitigation responses are identified below.

Battery capability

Batteries are an emerging technology, which is showing great potential as an alternative to thermal generation to secure power systems.

The System Plan includes a staged commissioning of high spec batteries to ease the current challenges on our power system and to activate more renewables.

A staged approach enables testing of battery capability to provide system security. It also allows the system to capture and benefit from improvements in battery technology and costs over the 10-year planning horizon of the System Plan.

While the analysis suggests that batteries can deliver necessary system security services, a mitigation strategy is the ability to pivot to traditional technologies, such as synchronous condensers with flywheels. Due to their cost and lower functionality, this may be a sub-optimal outcome but the System Plan does not close off the option if it is required.

Low investment in large-scale solar

The System Plan provides certainty on the timing and need for large-scale solar on the system. It also unlocks opportunities to minimise connection costs and maximise generation output through the concept of a Renewable Energy Hub.

External investment is the foundation for the Renewable Energy Hub with local demand and the planned retirement of thermal generators providing the business case for involvement. There is a risk that private investment in large-scale solar is slow and, in such an event, other strategies may be used to de-risk investment proposals.

Demand is higher than expected

The Sunshine for Sale scenario recognises the possibility of high growth in the Darwin-Katherine region leading to a steep increase in energy demand.

Under this scenario, the modelling suggests significantly higher amounts of large-scale solar will be required. A second Renewable Energy Hub could provide inter-connection possibilities with transportable solar at mass scale if required.

The System Plan also recognises that there is a goal of a 1GW plus economy by 2050.

6. Consultation and future analysis



Plans need to constantly adapt and evolve to accommodate feedback and new information. Over the coming year, the Territory Government will continue discussions with stakeholders about the Renewable Energy Target and net-zero emissions vision.

As a biennial document, there are opportunities for further research and analysis to inform the updated System Plan in 2023.

6.1. Engagement going forward

There are multiple stakeholders with an interest in how the Darwin-Katherine electricity system develops in the future. Most importantly, this includes the customers who want access to affordable, reliable and secure electricity.

But the plan also impacts industry participants, including the 3 government owned corporations and private investors.

In developing the plan, the government consulted with stakeholders who have provided input, suggestions and expert advice.

The Territory recognises that a further program of consultation will be necessary as specific actions are advanced to deliver the System Plan and in the lead-up to the biennial plan review.

This provides an opportunity to understand key concerns and hear different views. It also will help identify specific analysis leading up to our next System Plan update in 2023.

6.2. Implementation plan

The System Plan has intentionally sought to provide a strategic perspective of the investments necessary to meet the 50% Renewable Energy Target. It recognises that this will require significant implementation activity over the next two years, including careful consideration and action in the following areas.

- **Renewable Energy Hub:** Significant analysis will be required on site location, design, and construction of a Renewable Energy Hub by 2025. Consideration will also be required on communicating with potential large-scale solar and battery investors on the cost benefits of co-locating in the Renewable Energy Hub.
- **Security Batteries:** Consideration will need to be given to the funding, design, and installation of the high spec security batteries required under the System Plan.
- **Virtual Power Plant**: Careful consideration will need to be given to the design of the Virtual Power Plant.

6.3. Further analysis

The System Plan draws on extensive modelling, analysis and expert advice.

The level and scope of analysis could be scaled up in preparation for our next System Plan in 2023 in a few key areas.

- **Understanding cost and opportunities for necessary regulatory reform:** There may be more opportunities to lower costs by reviewing technical codes and standards. This may require transparent and informed conversation with customers and stakeholders.
- **Determining the limits of the power system:** The System Plan has taken a cautious approach to defining the limits of what the power system can deliver under disturbances. Further analysis may demonstrate that the system can achieve security and reliability even under more challenging circumstances.
- **Proving up the capabilities and value of batteries:** The System Plan views security and storage batteries as holding the key to moving to increased levels of renewables post 2030 in place of current reliance on thermal generation. The System Plan distinguishes between batteries for security and storage, but there are opportunities to unlock further value through batteries that are able to provide both storage and security services.

The System Plan is strategic and does not include analysis of operational and network needs. This operational analysis is the responsibility of government owned corporations and the outcomes of these assessments will also inform the 2023 Darwin-Katherine Electricity System Plan.

6.4. Next Darwin-Katherine Electricity System Plan

The System Plan is intended to be a biennially revised and updated document with the next version published in 2023. This will enable an assessment of progress toward the 2030 Renewable Energy Target, analysis of advances in technology and system planning, and any necessary revisions to current system infrastructure.

This will also provide opportunity to review and reset as required assumptions adopted in this System Plan such as the pace of growth in the renewables sector and energy demand patterns given the Territory Government's vision for a $40 billion economy by 2030.

Abbreviations

AEMO	Australian Energy Market Operator
CO_2-e	Carbon dioxide equivalent
BESS	Battery energy storage system
DER	Distributed Energy Resources
DKTL	Darwin-Katherine Transmission Line
ESS	Essential System Services
EV	Electric vehicle
FCAS	Frequency Control Ancillary Services
GW	Gigawatt
GWh	Gigawatt-hour
ISP	Integrated System Plan
kV	Kilovolt
MW	Megawatt
MWh	Megawatt-hour
NEM	National Electricity Market
NPV	Net Present Value
PV	Photovoltaic
RoCoF	Rate of Change of Frequency
VPP	Virtual Power Plant



Glossary

TERM	DEFINITION
Behind-the-meter	Energy production and storage systems that directly supply homes and buildings with electricity. Many maintain a connection to the electrical grid.
Contingency	The loss or failure of a part of the power system (e.g. transmission line), or of individual equipment (e.g. generator or transformer).
Curtail(ment)	A deliberate reduction in output (to a level below what could have been produced) in order to balance energy supply.
Dispatch(ability)	Electricity that can be sent out at the request of power grid operators depending on market demand
Distributed energy resources	Renewable energy units or systems commonly used in homes or businesses to provide them with power. Also referned to as 'behind the meter'.
Discharge (battery)	The process of using up all the energy stored in a rechargeable battery.
Essential system services / Frequency Services	Services used to manage the power system safely, securely, and reliably, by maintaining the key technical characteristics of the system such as frequency standards, voltage, network loading and system restart processes.
Frequency control	Helps the power system to constantly maintain a demand-supply balance, even following a major disturbance.
Generation mix	The combination of different types of fuels used to generate electricity.
High spec	High level of specifications or capability. In particular, high specification batteries refers to batteries capable of a fast response to provide various essential system services, rather than only providing energy storage services.
Inertia	The resistance of a body to changes in momentum. Energy stored in large rotation generators or industrial motors that gives them the ability to keep rotating and temporarily make up for power lost if a generator at a power plant fails.
Large-scale solar	Solar PV generation systems, typically greater than 100kW, and installed primarily for the commercial generation of electricity.
Renewable Energy Hub	A common area or precinct with shared assets where renewable energy (e.g. solar) is being generated, converted and/or stored by different energy operators.
Renewable Energy Target	50% of the electricity consumed in 2030 from grid-connected installations, including behind-the-meter generation and all Aboriginal communities supplied by Indigenous Essential Services, excluding self-generating enterprises that generate electricity for their own use in their primary business.

Renewables	An electrical generator that converts energy from a renewable source, such as the sun, to electricity. For example, a solar power generator is a renewable generator. Wind is another example of a renewable source.
Small-scale solar	Solar PV generation systems, typically smaller than 100kW, and installed primarily for on-site supply of electricity.
Spinning reserve	Electricity generation capacity held in reserve and ready to respond quickly if another generator experiences an unexpected outage so that the supply of electricity to customers is uninterrupted.
Solar farm	A large-scale solar installation capable of generating very large amounts of solar energy (e.g. from hundreds of killowatts to several gigawatts) to provide electricity consumers.
Synchronus condenser	Large rotating machine similar to a generator or motor, but where the rotor can spin freely. The synchronous condenser can be used to change power system conditions and when fitted with a flywheel, it can increase the level of available synchronous inertia.
System strength	Helps the power system maintain stability during a disturbance. Currently provided through thermal generation in the Northern Territory.
Thermal generator	Generators that convert heat energy to electricity by burning furels (e.g. natural gas).
Underlying energy / demand	All the electricity used by consumers, sourced from the grid as well as rooftop solar photovoltaic (PV) and battery storage.
Virtual Power Plant	A cloud-based network that aggregates and coordinates several different types of distributed energy resources, such as small-scale solar systems, hot water systems and batteries, to provide a more reliable overall power supply.
Voltage	The 'pressure' from an electrical power source that pushes current through the conducting loop.
Watt	The base unit of power equal to one joule per second.
Kilowatt	Equivalent to 1000 watts.
Megawatt	Equivalent to 1000 kilowatts.
Gigawatt	Equivalent to 1000 megawatts.
Watt-hour	A unit of electrical energy euql to the power of one watt in use for one hour. Often used as a unit of electricity consumption. (This applies to kilowatt-hours, megawatt hours, gigawatt-hours).

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