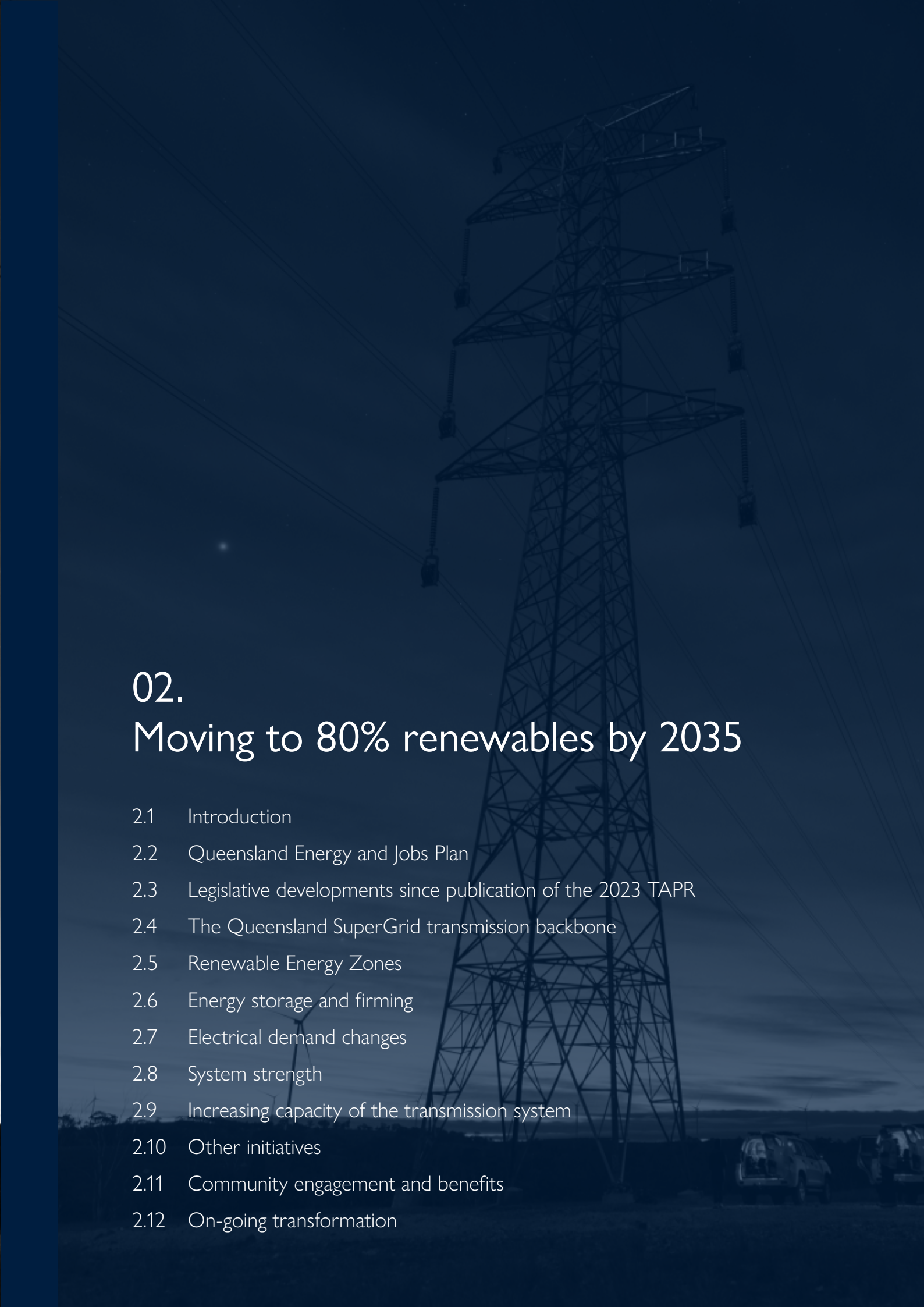


02.
Moving to 80% renewables by 2035

This chapter discusses Powerlink's critical and active role in the energy transformation. In developing the future network to support a move to net zero emissions, Powerlink is enabling diversity of generation and storage, supporting industry and load growth, exploring new technologies, and working closely with Queenslanders to ensure a cost effective, reliable, and secure electricity supply. The information discussed in this Chapter is provided in the context of the Queensland Energy and Jobs Plan (QEJP) and Queensland SuperGrid Infrastructure Blueprint (Infrastructure Blueprint) published in September 2022. The Infrastructure Blueprint is a point in time plan scheduled to be updated in May 2025.

Key highlights

- Powerlink is playing an active role in the energy transformation by strategically planning the transmission network, guiding and shaping the power system, and enabling opportunities as Queensland moves to a lower emissions future.
- Powerlink is working closely with the Queensland Government in developing and actioning the Queensland Energy and Jobs Plan (QEJP) including the establishment of new Renewable Energy Zones (REZ) and providing input on transmission development considerations and broader technical aspects associated with the energy transformation.
- Powerlink's long-term strategic planning approach comprises a series of staged low regret investments and remains focussed on delivering safe, reliable and affordable services taking into account:
  - the central role the transmission network will play in enabling the transformation to a lower emissions future
  - dynamic changes in the external environment including continued growth in Variable Renewable Energy (VRE), Consumer Energy Resources (CER) including rooftop photovoltaic (PV) systems, large and small-scale firming technologies, as well as broader shifts to electrification and decarbonisation within Queensland industries
  - the condition and performance of existing transmission network assets to plan the network in such a way that it is best configured to meet current and future energy needs while maintaining the flexibility to adapt as the transmission network need evolves.

2.1 Introduction

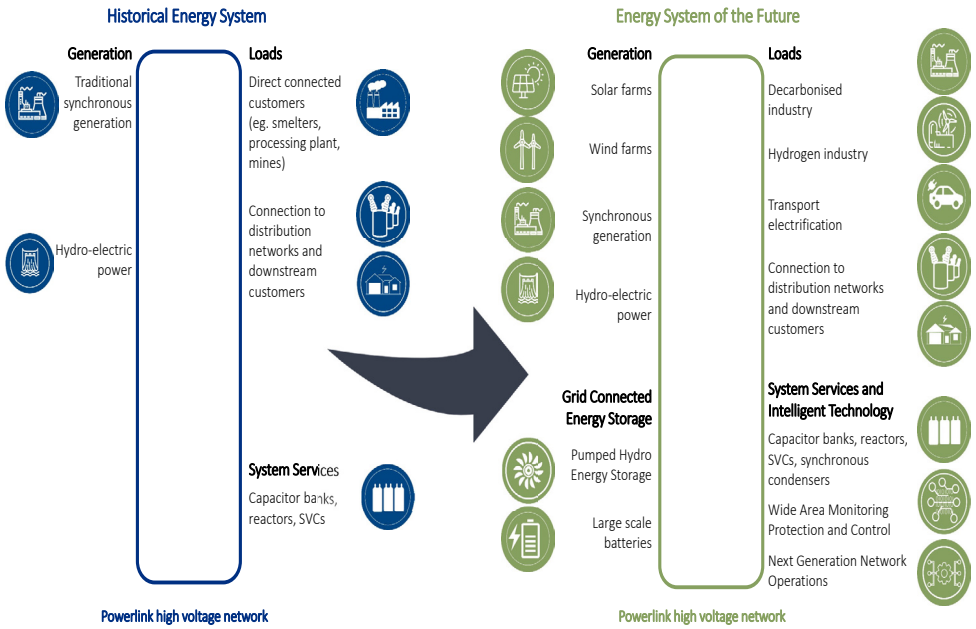
The transformation of the energy system within Queensland to one underpinned by clean, sustainable and affordable renewable energy is well underway. This is evident with an increasing share of large-scale VRE within the State and continued strong growth in the uptake of rooftop PV systems and large-scale batteries. Many corporations are committing to the decarbonisation of existing fossil fuelled operations and processes either through electrification or clean fuel substitution to leverage Queensland's abundant renewable energy resources.

The energy system of the future will be characterised by a mix of technologies and infrastructure along the entire energy supply chain to transform to net zero emissions. It will look considerably different to the energy system of the past with large-scale renewable energy generation, long-duration Pumped Hydro Energy Storage (PHES) and Battery Energy Storage Systems (BESS), electrified industrial and transport sectors, emerging green industries, CER, and intelligent control and orchestration being integral components of the decarbonised energy system (refer to Figure 2.1).

The transmission system plays a critical role as the platform for the efficient large-scale transportation of renewable energy and storage. As the Jurisdictional Planning Body (JPB) and Transmission Network Service Provider (TNSP) within Queensland, Powerlink is playing an active role in shaping and enabling the power system of the future.

Powerlink has also been designated new roles under legislation recently enacted by the Queensland Government in April 2024. These roles comprise the REZ Delivery Body (RDB) and REZ TNSP for Queensland. Powerlink continues to work closely with the Queensland Government providing technical insights on transmission network developments on optimal pathways to achieve 80% renewables by 2035, 75% economy-wide carbon emissions reductions on 2005 levels by 2035, and net zero emissions by 2050.

Figure 2.1 Energy system of the future



2.2 Queensland Energy and Jobs Plan

In September 2022, the Queensland Government published the Queensland Energy and Jobs Plan (QEJP). This plan sets out the roadmap for the transformation of the energy system and adds to Queensland's existing renewable energy targets. The plan also details a range of initiatives and foundational investments to achieve these targets.

The Queensland SuperGrid Infrastructure Blueprint ("Infrastructure Blueprint") was published by the Queensland Government in conjunction with the QEJP. The Infrastructure Blueprint outlines the Optimal Infrastructure Pathway (OIP) to deliver a clean, reliable and affordable power system. Powerlink continues to inform and provide context to the broader technical aspects associated with the energy transformation.

2.2.1 Adapting to changes in the external environment

The Infrastructure Blueprint is a point in time plan with the underlying inputs, assumptions and future scenarios continually monitored as the market evolves and the quality of available information improves as part of detailed design and planning phases. The Queensland Government is required to update its Infrastructure Blueprint every two years with the OIP to reflect new infrastructure investments, changing market conditions, and the market outlook. The next update to the Infrastructure Blueprint is scheduled for May 2025 and will be discussed in Powerlink's 2025 Transmission Annual Planning Report.

2.3 Legislative developments since publication of the 2023 TAPR

The Queensland Government has passed new legislation to drive clean economy investments, support new green industries and jobs, and lay the pathway for transformation of the energy system to one underpinned by reliable and affordable renewable energy.

On the 18 April 2024, the Queensland Government passed the Clean Economy Jobs Act 2024 making a significant move towards realising a clean economy future for Queensland. This legislation aims to drive investment and jobs with a new emissions reduction target of 75% below 2005 levels by 2035 as well as enshrining in legislation Queensland's commitment to net zero emissions by 2050.

The Queensland Government also passed the Energy (Renewable Transformation and Jobs) Act 2024 (ERTJ Act) on the 18 April 2024. The Act enshrines three State Renewable Energy Targets in legislation and creates frameworks for building the Queensland SuperGrid. The Act establishes governance and advisory bodies to ensure a smooth and co-ordinated energy transformation providing crucial steps towards a clean, reliable, and affordable energy future for Queensland. The Act also sets out the process to allow the Queensland Government to identify and assess Priority Transmission Investment (PTI) projects within a new State-based planning and investment framework, and to direct Powerlink to construct these projects and recover its costs following completion of assessment activities.

The Infrastructure Blueprint identifies eligible PTIs. Powerlink is required to undertake public consultation processes as part of the assessment stages of the PTI process and will invite written responses to consultations from energy industry participants, energy market bodies, potential non-network solution providers, and any other interested parties. PTIs may provide opportunities for non-network solutions and providers of potential solutions are encouraged to provide a written response to PTI consultations to enable a full assessment of all credible options.

In July 2024, Powerlink commenced consultation on the Gladstone Project as a candidate PTI under the ERTJ Act. This consultation is being undertaken to ensure that on-going reliability and security of supply is available to meet forecast electrical load in the Gladstone area and support the decarbonisation of major industries in anticipation of the closure of the Gladstone Power Station. Further details on this consultation and next steps are provided within Section 6.6.2 and Powerlink's website[1].

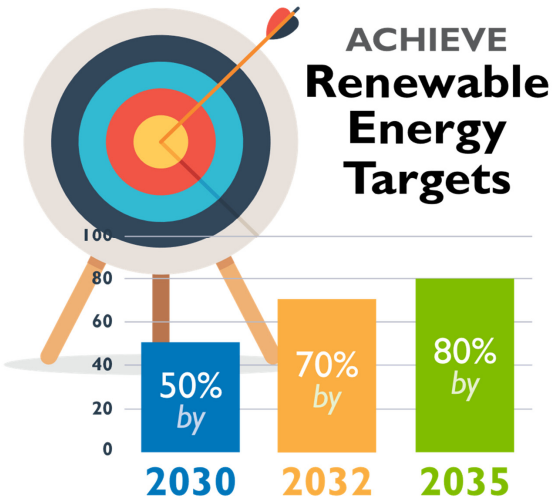
2.3.1 Renewable Energy Targets

The ERTJ Act 2024 enshrines State Renewable Energy Targets into legislation (refer to Figure 2.2).

Queensland is well on track to meeting these renewable energy targets. The construction of a number of large-scale renewable energy projects within Queensland and the continued strong uptake of rooftop solar PV systems has meant that steady progress is being made towards meeting these targets.

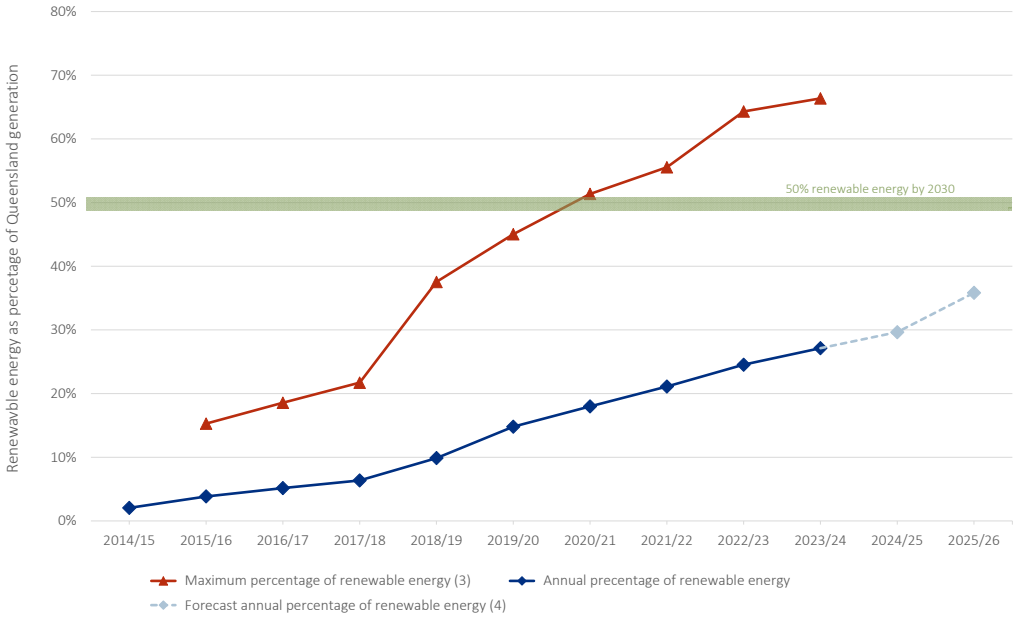
The maximum percentage of renewable energy generation has also been steadily increasing. The peak percentage of renewable energy across the most recent financial year has now exceeded 65% (refer to Figure 2.3).

Figure 2.2 Queensland renewable energy targets[2]



[1] Refer www.powerlink.com.au/priority-transmission-investment-gladstone-project.
[2] Source: Queensland Energy and Jobs Plan Overview.

Figure 2.3 Queensland percentage of renewable energy generation (1) (2)



Notes:

(1) Annual average and maximum percentage of renewable energy generation based on AEMO and Clean Energy Regulator data.

(2) Percentage of renewable energy calculation methodology as per Queensland Government website. Refer www.energyandclimate.qld.gov.au/about/initiatives/renewable-energy-targets

(3) Maximum percentage of renewable energy refers to the highest percentage of renewable energy generated in a trading interval during the financial year.

(4) Forecast annual percentage of renewable energy includes renewable generation projects currently under construction and undergoing commissioning. Capacity factors for new renewable generating stations are based on existing stations of similar technology within the vicinity. Rooftop PV is included within renewable energy generation with forecasts based on the AEMO 2024 ISP Step Change scenario.

2.4 The Queensland SuperGrid transmission backbone

The Queensland SuperGrid detailed within the Infrastructure Blueprint includes a number of inter-related elements comprising renewable generation, firming of intermittent generation, and the transmission network.

A key part of the OIP transmission infrastructure detailed within the Infrastructure Blueprint is a new high capacity transmission backbone to enable the efficient transportation of renewable energy and storage across the State taking advantage of daily and seasonal diversity of renewable energy resources. The Infrastructure Blueprint provides foundations for the next stages of optimisation whilst acknowledging the need to take account the dynamic nature of the power system including market development opportunities, technical performance, and technology changes.

Subject to shareholding Minister approval, the SuperGrid transmission backbone will be developed in stages to provide connection capacity for new PHES facilities and access to Queensland's high quality renewable energy resources. The Infrastructure Blueprint currently identifies the first stage as the delivery of a high capacity transmission line connection between Halys (near Kingaroy) and Woolooga (near Gympie) for the bulk transfer of power. The transmission line would also serve to connect Borumba Pumped Hydro Energy Storage (PHES) into the transmission network.

The second stage of the SuperGrid provides a high capacity transmission line between Southern Queensland (SQ) and Central Queensland (CQ). The connection is planned to increase transfer capacity between SQ and CQ and support predicted load growth in the Gladstone region. The augmentation will also further support the hosting of renewable generation connections in South and Central Queensland.

The third stage of the SuperGrid transmission backbone involves transmission connections from Townsville through to Central Queensland, enabling connection of the proposed PHES to load within the Gladstone area as well as harnessing the diverse and high quality wind resource in northern and western Queensland.

The fourth stage of the SuperGrid is the Townsville to Hughenden transmission development. In June 2023, the Queensland Government announced that the fourth stage of the SuperGrid will be advanced and form part of CopperString 2032. This critical infrastructure development will be publicly owned with Powerlink building and operating the new transmission connection (refer to Section 2.4.1).

In July 2024, an update was made to the second stage of the SuperGrid strategy to shift the original location from a coastal to an inland route. This alignment change is based on the significant interest from renewable energy companies to develop wind farms to the west of the original alignment. The ability to leverage this wind resource through an altered alignment will benefit Queensland by reducing the costs of connecting transmission infrastructure, increasing the pace of renewable development and associated decarbonisation. That is, routing the SuperGrid connection via an inland alignment will result in a more coordinated solution with shorter transmission connections to each wind farm and a significant reduction in the overall footprint of transmission infrastructure. This strategy also allows transmission development to be built in stages and paced to align with interest for renewable connections.

Powerlink will commence planning a high capacity transmission line between Halys and the Gladstone area as part of the updated SuperGrid transmission backbone strategy. Powerlink will engage extensively with the community and stakeholders during Transmission Easement Engagement Processes to identify a corridor that leads to the best overall outcomes from a social, environmental and economic perspective.

The establishment of a transmission line of up to 500kV along the inland corridor between South Queensland and Central Queensland enables the first stage of the SuperGrid transmission backbone from Halys to Woolooga to be constructed at 275kV rather than 500kV. The updated Queensland SuperGrid transmission backbone is shown in Figure 2.4.

Figure 2.4 Queensland SuperGrid transmission backbone

Note: Powerlink is currently progressing consultation on the Gladstone Project as a candidate PTI (refer to sections 2.3 and 6.6).

2.4.1 CopperString 2032

The CopperString 2032 project involves constructing 840km of high voltage transmission line from Townsville to Mount Isa that will connect the North West Mineral Province (NWMP) to the National Electricity Market (NEM). CopperString 2032 will form an essential part of the Queensland SuperGrid transmission backbone. Powerlink took ownership of the project from CuString Pty Ltd in March 2023, and will build and own CopperString 2032, leading delivery of the project to completion.

The connection of the NWMP will link one of the richest mineral deposits in the world to the NEM. These minerals are essential for the production of components within electric vehicles, battery systems, and other products to aid the shift to decarbonisation.

CopperString 2032 is anticipated to significantly bolster new industries and facilities for minerals mining and processing in north west Queensland. For example, a consortium of three major companies has recently signed a collaboration agreement to build an end-to-end manufacturing chain for vanadium flow batteries in north Queensland.

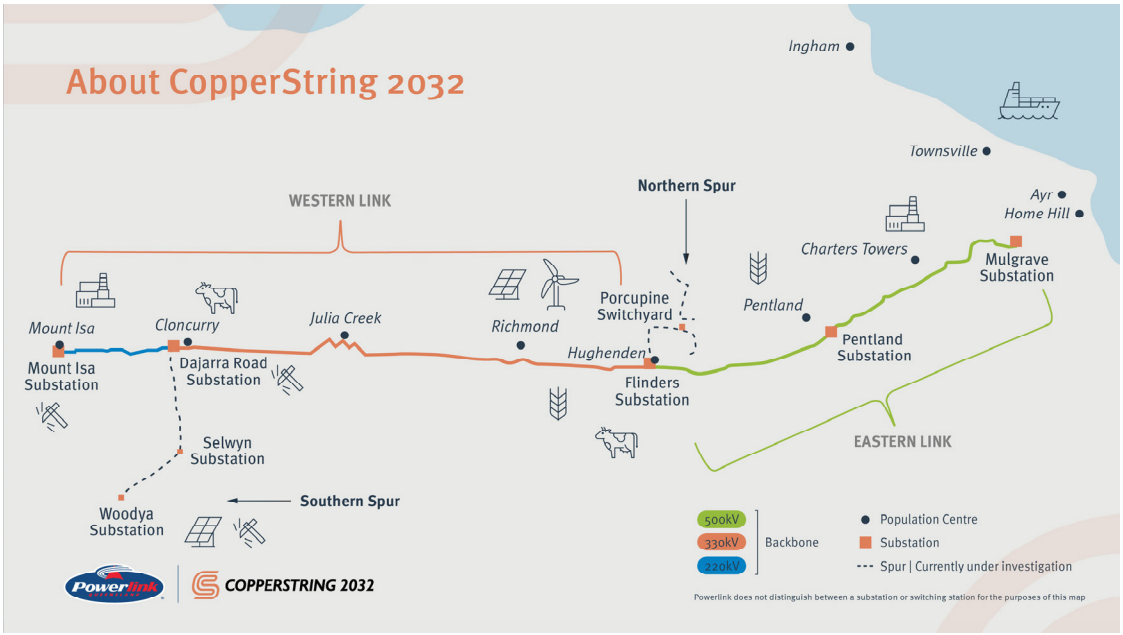
CopperString 2032 will also enable the connection of significant quantities of renewable energy from north west Queensland to the rest of Queensland. The Hughenden region has the potential to host significant levels of new wind generation which has complementary properties to wind output in other parts of the State particularly during winter and night time periods. The Hughenden region has been designated as Flinders REZ within the 2024 Queensland Government REZ Roadmap (refer to Section 2.5.5).

The CopperString 2032 project includes the following core transmission infrastructure components:

- construction of new 500kV double circuit transmission line from Townsville to Hughenden (Stage 4)
- construction of new 330kV double circuit transmission line from Hughenden to Cloncurry
- construction of new 220kV double circuit transmission line from Cloncurry to Mount Isa
- establishment of new substations, and installation of transformers and reactive plant.

It is also anticipated that further transmission lines will be constructed to connect diverse wind renewable energy to Flinders Substation following the CopperString 2032 project.

Figure 2.5 CopperString 2032 transmission development



The Australian Energy Market Operator (AEMO) has included the CopperString 2032 project as an Anticipated Project within the recently published AEMO 2024 Integrated System Plan.

2.5 Renewable Energy Zones

A REZ is a geographic area which has significant high quality renewable resources, suitable topography, and available land to support the efficient connection of a number of large-scale renewable energy projects. Development of a REZ allows multiple grid-scale renewable energy developments to be connected in the one location realising economies of scale and enabling the connection of grid-connected renewable energy in a more cost effective and streamlined manner therefore benefiting communities, developers and consumers. The development of REZs streamlines implementation of renewable energy projects by leveraging common infrastructure.

Queensland is an attractive location for grid-scale VRE generation as the state is rich in a diverse range of renewable resources. The establishment of REZs enables optimisation through co-ordination of large-scale renewable generation, transmission network, energy storage and firming, and ancillary system services to maximise the potential capacity of renewable energy in a cost-efficient manner, while reducing investment risk and financing cost for developers.

The Queensland Government has undertaken a range of initiatives to make the connection process to REZs smoother and simpler for developers, and to establish on-going benefits for landholders, communities, and other stakeholders in these areas. Powerlink has worked closely with the Queensland Government on these initiatives.

2.5.1 Queensland's REZ Model

Queensland has implemented a market-led REZ approach. This model is characterised by Powerlink working with renewable energy companies to identify projects which are of a size and maturity to drive efficient development of REZs. The model helps reduce landholder, environmental and community impacts as well as risk and costs, and is funded by the renewable energy companies connecting to the REZ.

This approach delivers benefits for developers by unlocking additional streamlined opportunities to connect to the network increasing the cost effectiveness of connecting and optimising the capability of the system. Key principles of this approach include:

- supporting connection of new generation at locations with high resource quality relatively close to the transmission network
- using existing network capacity
- developing REZs in a scale-efficient way to maximise hosting capacity and system strength at lowest cost
- reduced individual proponent connection costs
- simplicity and transparency in the connection process
- clear and consistent community engagement requirements
- speed of connections.

While REZs aim to achieve similar energy transformation goals, each declared REZ in Queensland will be unique. The approach and design of each REZ will consider specific locational characteristics, geography, connection into shared transmission infrastructure, resource availability and community context.

2.5.2 Queensland REZ Roadmap

In March 2024, the Queensland Government published the 2024 Queensland Renewable Energy Zone Roadmap following extensive consultation with stakeholders and communities across the State. The Roadmap outlines the pathway for connecting 25GW of large-scale renewable energy by 2035 and is a key component of the QEJP and commitment to meet Queensland's renewable energy targets. The Roadmap provides transparency over likely future REZ locations in Queensland to help improve long-term regional planning and co-ordination.

The Queensland Government has published key insights and lessons from consultation with local communities on the draft 2023 REZ Roadmap. The Stakeholder Insights on the Energy Transformation provides critical insights on how to best deliver the energy transformation for regional communities and improve outcomes. The Queensland Government has committed to updating the Queensland REZ Roadmap every two years aligned with the Queensland SuperGrid Infrastructure Blueprint to reflect the latest market outlook and developments.

Powerlink provided significant input to developing the Queensland REZ Roadmap. The Queensland Government and Powerlink have undertaken analysis to determine where potential REZs could be established. The analysis has identified 12 potential REZ locations across the Far North, North, Central and Southern regions of the state (refer to Figure 2.6). These indicative REZ locations have been identified based on analysis of a range of factors. As the jurisdictional planning body for Queensland, Powerlink has examined the capability of the transmission network to determine optimal locations for development of REZs. The assessment also included an appraisal of renewable investor development interest.

The identified REZs will be developed over three phases to facilitate staged implementation of large-scale renewable generation:

- Phase 1 – Building on our strong foundations (early to mid 2020s)
- Phase 2 – Scaling and expanding opportunities (mid to late 2020s)
- Phase 3 – Preparing for net zero by 2050 (early 2030s).

The three phases take into account the sequencing of other large-scale energy infrastructure developments including the SuperGrid transmission backbone, and long duration PHES facilities.

It should be noted that the hosting capacity, location, and timing of REZs may change over time based on analysis of market forces, available network capacity, renewable resources, investor interest, land use, and other factors. The precise footprint of REZ infrastructure, including network, generation, storage, and system services facilities, will be developed on a case by case basis. Additional future REZs may also be identified to meet growing demand from decarbonisation and electrification of existing industries, new green industries, and other load developments.

2.5.3 New Roles for Powerlink

There are two new distinct roles for the delivery of Queensland REZs within the ERTJ Act 2024.

The first role is performing the function of RDB. The Queensland Government has appointed Powerlink as the RDB effective from 1 July 2024. The RDB is responsible for identifying areas suitable to be a REZ, developing draft and final REZ Management Plans (RMP) to enable the declaration of the REZ, and consulting with communities and stakeholders.

The second role involves Powerlink performing the function of the REZ TNSP. Powerlink will be responsible for planning, design, owning, constructing, operating and maintaining REZ transmission infrastructure and undertaking processes for the connection of renewable generation. It should be noted that infrastructure linked to REZs will not be open access and will follow processes prescribed in the RMP to optimise Queensland renewable generation.

2.5.4 Delivery of Renewable Energy Zones

The delivery of REZs within Queensland is well underway. In June 2024, Powerlink commissioned the Far North Queensland REZ with the Kaban Green Power Hub as the foundation customer. The development of this REZ commenced prior to the establishment of provisions contained within the ERTJ Act 2024, and hence was designated as one of the inflight REZs within the Queensland 2024 REZ Roadmap.

Southern Downs and Western Downs REZ in southern Queensland have also been significantly progressed. These REZs have also been designated as inflight REZs within the Queensland 2024 REZ Roadmap. Powerlink completed construction and energised the 330kV transmission network for the Southern Downs REZ in December 2023. The Western Downs REZ is scheduled to be energised towards the end of 2024.

Powerlink is also progressing the planning for Callide REZ located in Central Queensland. The development of this REZ and enabling infrastructure will be carried out under provisions within the new ERTJ Act 2024. Powerlink will develop this REZ and enabling infrastructures as part of RDB and REZ TNSP responsibilities.

2.5.5 Potential Queensland Renewable Energy Zones

The Queensland Government REZ Roadmap contained 12 potential REZs. Further details on these REZs are provided below and in Table 2.1.

Far North and North Queensland

The Far North and North Queensland areas offer rich wind and solar renewable energy resources. The CopperString 2032 project is set to open up the Hughenden region for substantial wind and solar renewable energy development. Renewable energy in this area is in proximity to the planned development of PHES and emerging green industry within the Townsville and Bowen areas. Powerlink has also established an interim transmission and training hub in Townsville to provide local engineering and field services to support development and maintenance of the transmission network in North Queensland (refer to Section 2.10). A permanent hub will be established in Townsville in coming years.

Powerlink commissioned the Far North Queensland REZ in June 2024. Two additional REZs are earmarked for this area. The Collinsville and Flinders REZs are anticipated to provide around 4GW of hosting capacity.

Central Queensland

The Central Queensland region offers strong opportunities for both wind and solar renewable energy and is well placed to capitalise on the decarbonisation and electrification of industrial and metals processing facilities and emergence of new green industry within the Gladstone area.

There are four candidate REZs proposed for Central Queensland. The Callide and Calliope REZs will form the first stages of REZ developments anticipated to provide more than 4GW of combined hosting capacity.

The Isaac and Capricorn REZs are anticipated to form the second stage of REZ development providing around 3GW of hosting capacity.

Southern Queensland

Southern Queensland also provides attractive opportunities for large-scale wind and solar renewable energy generation particularly within the south western part of the region. A number of wind farms have recently been commissioned or are in advanced stages of construction within this area. Renewable energy resources in south west Queensland are in proximity to energy intensive agribusinesses in the region that are looking to decarbonise. The south west Queensland area is also expected to provide renewable energy to major load centres within South East Queensland via the SuperGrid.

There are currently two inflight REZs for South Queensland. The Southern Downs and Western Downs REZs are expected to have a combined network hosting capacity exceeding 4GW. Powerlink has completed construction and energised the 330kV transmission network for the Southern Downs REZ and is progressing the construction of 275kV network for the Western Downs REZ.

There are three additional REZs proposed for south Queensland. The Woolooga and Darling Downs REZs form part of the second stage of REZ development within the Roadmap and are expected to provide around 4GW of combined hosting capacity. The Tarong REZ forms part of the third stage of REZ development and will be developed to align with the establishment of other large-scale energy infrastructure.

Table 2.1 Expected REZ installed generation within the 2024 Queensland REZ Roadmap (1)

Region	REZ	Expected installed generation	In-flight	Phase 1	Phase 2	Phase 3
Far North and North Queensland	Far North Queensland	500 to 700MW	✓ (2)			
	Collinsville	1600 to 2000MW			✓	
	Flinders	2000 to 2400MW			✓	
Central Queensland	Callide	2000 to 2600MW		✓		
	Calliope	1500 to 2000MW		✓		
	Isaac	1400 to 1800MW			✓	
	Capricorn	1400 to 1800MW			✓	
Southern Queensland	Southern Downs	2000 to 2600MW	✓ (3)			
	Western Downs	2000 to 2600MW	✓			
	Woolooga	1600 to 2000MW			✓	
	Darling Downs	1600 to 2000MW			✓	
	Tarong	2000 to 2400MW				✓

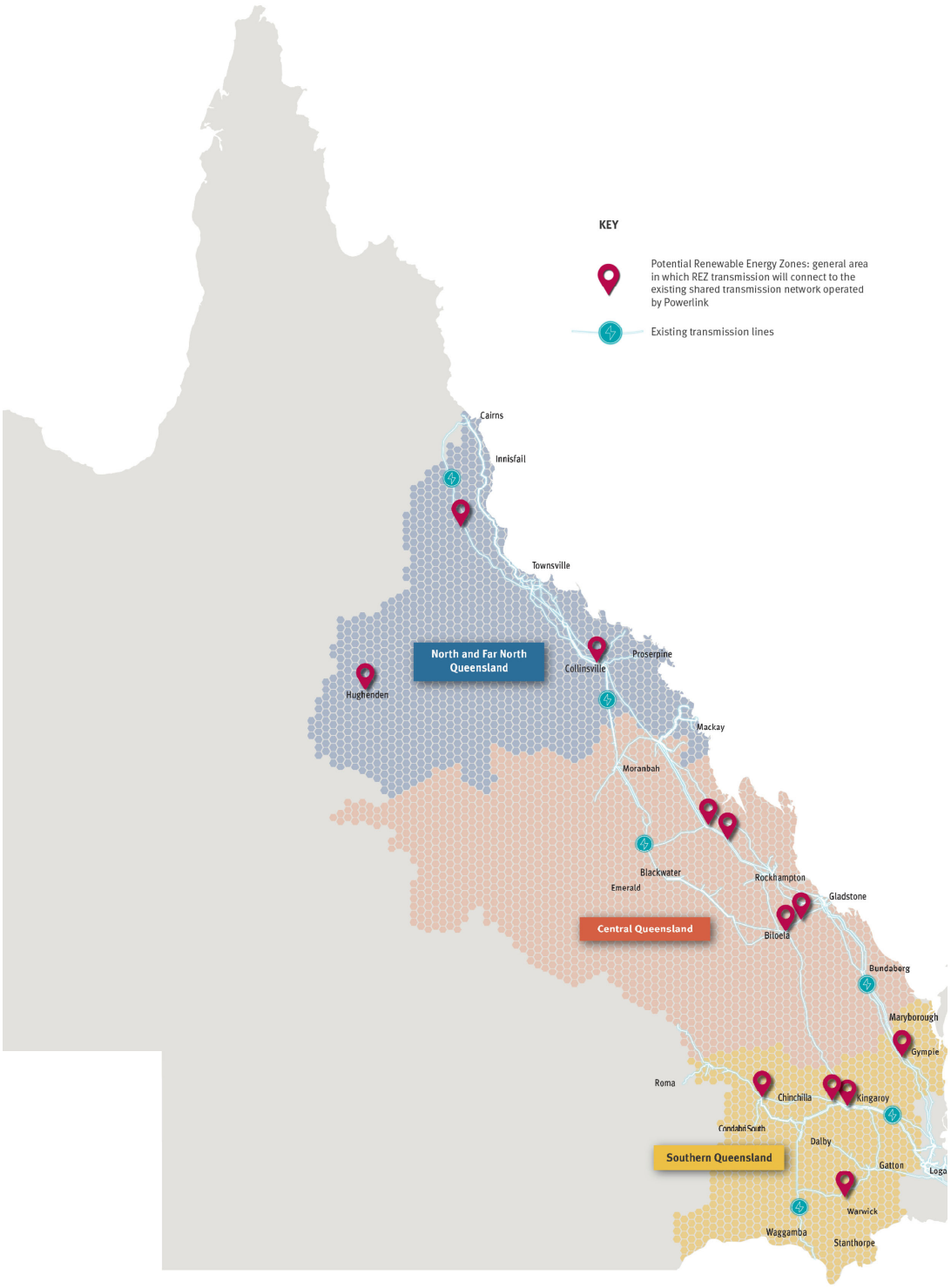
Notes:

(1) Source: Queensland Government 2024 REZ Roadmap.

(2) Powerlink commissioned the Far North Queensland REZ in June 2024.

(3) Powerlink completed construction of the 330kV transmission network for the Southern Downs REZ in December 2023.

Figure 2.6 Potential REZs outlined within the 2024 Queensland Government REZ Roadmap (1)



Source: Queensland Government 2024 REZ Roadmap.

2.6 Energy storage and firming

The ability for large-scale electrified industrial processes to operate more flexibly in response to an abundance or scarcity of renewable generation can help reduce the need for additional firming and storage. There is currently limited (continuous) demand side participation within the Queensland energy system. However, the value of demand-side responses is expected to increase as the supply-side becomes dominated by weather-dependent intermittent sources. The potential for load flexibility is expected to increase as more industrial processes decarbonise and transform to electrified operation, and new green industries are established.

Demand response through CER, including household battery systems, electric vehicles, and household electric usage patterns, have played a limited role in firming to date. However, there are opportunities for CER to play a greater and more integral role in the energy transformation.

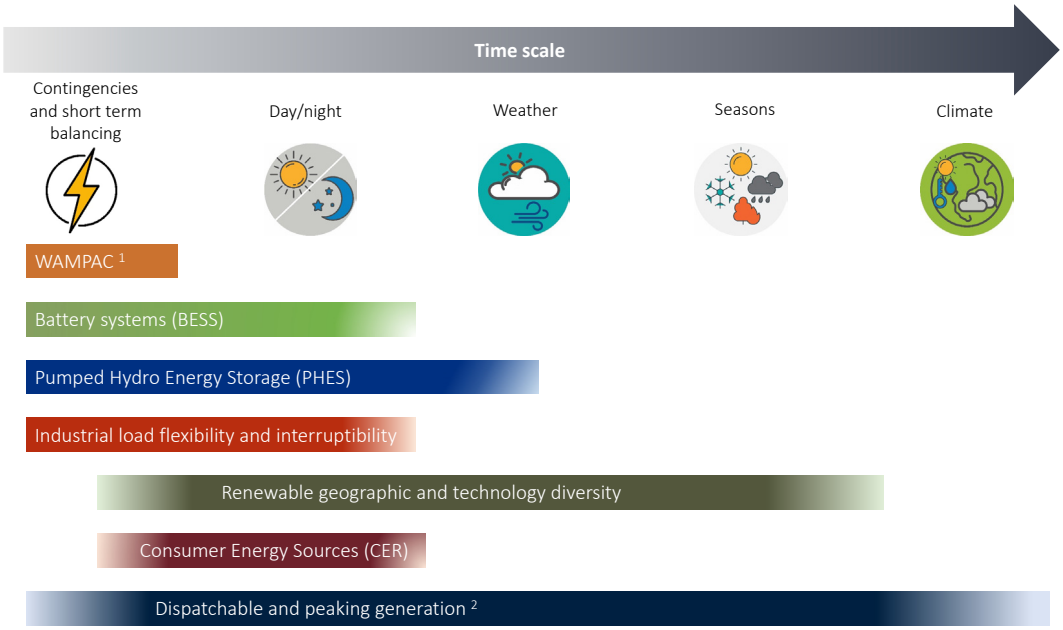
Energy storage and firming services will form an integral part of the future mix of technologies in Queensland. Energy storage services appropriately located and sized will increase the reliability of supply from intermittent generation sources by shifting energy to manage peaks and troughs associated with weather conditions and consumer demand, whilst also providing a number of ancillary services to keep the energy system secure. The energy system of the future will require a mix of energy storage services including PHES, large-scale grid-connected BESS, community battery systems, and residential battery systems.

PHES are utility-scale energy storage systems which deliver hydro-electric power generated through the release of water from an upper reservoir to a lower elevation reservoir, and store energy by using the same machines to pump water from the lower reservoir to the upper reservoir. These systems are generally larger in scale and provide longer duration energy storage whereas battery systems provide energy at smaller storage scales with a faster response over shorter periods. Both technologies will provide a critical role in energy firming and addressing challenges of minimum demand through the ability to pump or charge during periods of abundant renewable energy output to store energy. These technologies will also provide critical system security services necessary to support the power system including voltage and frequency control, system strength, and inertia.

The optimal mix of technologies and services involves an economic trade-off whilst also taking into account environmental and social factors. The use of dispatchable generating sources including natural gas, renewable fuels, and hydrogen generation is expected to play an important role in addressing extremities with weather and climatic conditions. A renewable generation mix which is both geographic and technologically diverse through prudent subscription of REZs, development of appropriately sized intra-regional transmission and interconnections with other regions will also help address and manage supply intermittency.

The nature and mix of energy storage and firming services within Queensland will be required to operate across a range of time scales and operating conditions to ensure reliability of supply. These operating horizons range from very short response periods (e.g. such as those during network contingencies) to longer periods across seasons and multi-year periods reflecting climate variations. Potential technologies likely to play an integral role in the firming of energy across the range of time scales are outlined in Figure 2.7.

Figure 2.7 Potential roles of firming technologies and services across time scale ranges



Notes:

(1) Further information on WAMPAC (Wide Area Monitoring Protection and Control) provided within Section 2.9.

(2) Dispatchable and peaking generation includes natural gas, renewable fuels, and hydrogen generation.

2.6.1 Pumped Hydro Energy Storage

The QEJP details the establishment of two publicly owned long duration PHES facilities. Large-scale deep storage facilities are essential for the energy transformation and facilitate the integration of large amounts of renewable energy. Subject to planning approvals, the two facilities comprise the Borumba PHES located south west of Gympie and the proposed Pioneer-Burdekin PHES located within North Queensland.

Borumba PHES

The Borumba PHES was selected as the first site for development following a state-wide assessment of potential pumped hydro locations. The facility is expected to be capable of generating up to 2GW of power for a period of 24 hours. The site is located in close proximity to several existing transmission corridors within southern Queensland and is strategically located to provide firming and system support services for significant renewable energy generation development within South Queensland. Queensland Hydro is undertaking environmental impact assessments, detailed engineering, geo-technical testing, civil infrastructure upgrades, and other delivery activities for the facility.

The Borumba PHES is planned to connect to the new high capacity transmission line between Halys and Woolooga substations, established as the first stage of the SuperGrid (refer to Section 2.4). The Borumba PHES and associated connections will provide long duration deep firming services essential to support the transformation to net zero emissions.

Pioneer-Burdekin PHES

The Pioneer Valley and adjacent ranges located approximately 75km west of Mackay were identified as an area with significant potential for a long-duration PHES facility. This was due to its favourable topography and proximity to high quality wind and solar generation sources in central and north Queensland.

The proposed Pioneer-Burdekin PHES is anticipated to have an energy storage capacity of up to 120GWh, allowing generating or pumping at 5GW over 24 hours. This PHES enables large-scale storage and transportation of renewable energy to support the decarbonisation and electrification of existing industrial processes and enable the development of new green industries. Queensland Hydro is undertaking a range of investigations to gain a comprehensive understanding of the project site.

Other PHES developments

Powerlink has been engaged by Genex Power Limited (Genex) to undertake a range of activities relating to the development of a 275kV electricity transmission line and associated substations for the connection of the Kidston Clean Energy Hub located in north Queensland (approximately 270km north west of Townsville). This renewable energy facility includes the construction of a 250MW / 2000MWh PHES facility (K2-Hydro) expected to commence operations in 2025.

There are numerous other PHES projects being progressed by the private sector which are in various stages of development. These projects will also form key infrastructure facilities to enable the energy transformation within Queensland.

2.6.2 Battery Energy Storage Systems

Grid-scale BESS, including those supported by advanced grid-forming inverter technology, will play a greater role in the transmission network and in providing system security services such as ramping support, managing shorter-term energy balancing, frequency regulation, voltage control, virtual inertia, and system strength. Grid-forming batteries can play an important role in increasing the hosting capability of inverter-based renewable generation and supporting the secure operation of the power system.

Grid-scale batteries can also play a role as Virtual Transmission Lines (VTLs). This offers the potential to alleviate transmission congestion and defer the need for network augmentations. Furthermore, large-scale battery services can be used to manage the impact of network outages by reducing constraints on generation, and potentially provide other support and ancillary services for the transmission network.

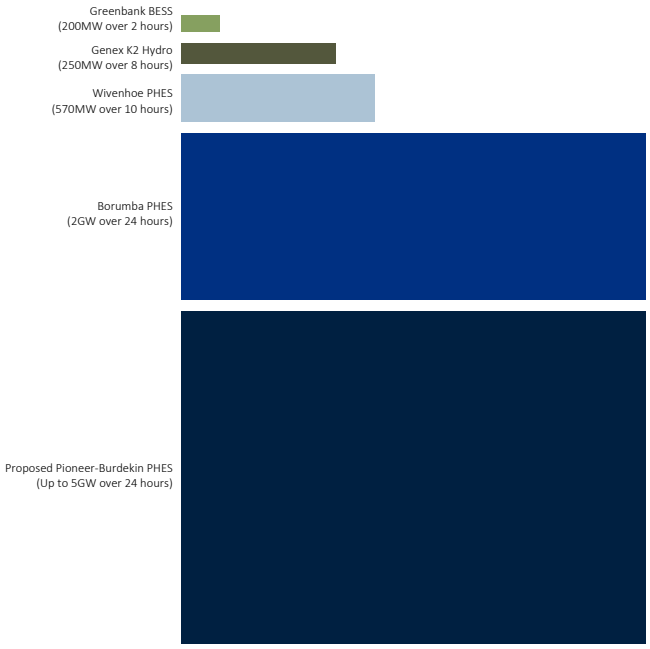
Queensland's first large-scale BESS (100MW / 150MWh) was connected to Powerlink's transmission network at Wandoan South Substation in 2022. A second large-scale BESS built by Genex Power (50MW / 100MWh) connected to Powerlink's transmission network at Bouldercombe substation near Rockhampton commencing operation in June 2023.

Powerlink is continuing to experience strong interest in the development and connection of large-scale BESS facilities across Queensland. There are a significant number of additional large-scale grid connected BESS in advanced stages of construction which are expected to be operational over the near term. Powerlink is currently progressing construction works for 755MW of large-scale BESS projects with total energy storage capacity of 1098MWh. These projects are under construction in a number of locations across the State (refer to Section 9.2).

2.6.3 Comparison of energy storage systems

An indication of the relative sizes of energy storage for existing and proposed storage infrastructure projects within Queensland are shown in Figure 2.8.

Figure 2.8 Relative energy storage capacities of PHES and BESS



2.7 Electrical demand changes

The electrification of major industrial processes, mining operations, and transportation will be an integral component of Australia's pathway to net zero emissions. Access to a safe, cost effective and reliable transmission network will be pivotal in enabling sectors to electrify operations with renewable generation sources, and for Queensland to transform into a renewable energy exporter.

The electrification of existing fossil fuel operations and processes present the primary avenue for decarbonisation. It has been estimated that around 20% of the energy needs of existing Queensland industries are currently met through electricity, and that around 60% of Queensland's energy consumption has the potential for direct electrical substitution through use of existing and emerging commercialised technologies. The remaining 20% of consumption within the state comprises of energy that is expected to require further technological development for energy substitution.

2.7.1 Decarbonisation through electrification

The nature and concentration of energy use across the State varies considerably depending on the category of customer. There are significant mining operations within the central west and north Queensland zones, and electrification of mining operations will impact on transmission capacity requirements to these areas. LNG extraction and compression facilities are concentrated within the Surat and Gladstone zones, and there are significant opportunities to decarbonise these processes through electrification.

Powerlink has experienced significant interest from large industrial customers looking to decarbonise their operations through electrification, and the emergence of new hydrogen and ammonia based industries and associated manufacturing facilities. In aggregate these developments can require significant increases to transmission capacity, with demand potentially exceeding several gigawatts ramping over time from the 2030s. They also have the potential to significantly alter energy flow patterns and power transfer capability requirements across Powerlink's high voltage network (refer to Chapter 8).

The degree of flexibility of these processes in terms of electrical demand consumption and interruptibility under contingency or outage conditions will be an important consideration in transmission network design and firming resources to support the energy transformation (refer to Section 2.6).

The transport sector presents one of the largest opportunities for decarbonisation. The adoption of electric vehicles (EVs) presents a near term opportunity for increasing electrification and decarbonisation. The charging behaviour and patterns for EVs has the potential to either support or challenge network requirements. The management of EV charging will be important to optimising the utilisation of the network.

EVs have the potential for dual purpose application in terms of providing both transportation and a household energy source. Vehicle battery capacities are generally larger than typical household daily use, and over time it may be possible to leverage this capacity back into the system to smooth daily demand usage patterns and rooftop PV output. Both residential battery systems and EVs have the potential to increase transmission and distribution network utilisation under appropriately designed orchestration incentives and mechanisms.

2.7.2 Emerging hydrogen industry

The Queensland Government has stated that it is committed to working with industry to accelerate the development of hydrogen related industries, including the production and export of hydrogen and manufacturing of associated hydrogen industrial components. Queensland is well placed for the development of a range of hydrogen production and secondary supporting manufacturing industries due to the prevalence of large-scale renewable energy development, available land, and proximity to ports particularly within the Townsville, Bowen, Gladstone, and Brisbane Trade Coast areas. Potential markets include both domestic hydrogen to decarbonise existing industrial processes and the establishment of new hydrogen export markets.

2.7.3 Rooftop photovoltaic systems

The uptake of rooftop PV systems within both residential and commercial premises in Queensland continues to be strong. There is now around 6.4GW of household and commercial rooftop systems connected to the network (refer to Section 3.2.1).

The uptake and development of distribution level renewable energy and rooftop PV systems continues to progressively deepen the characteristic duck curve observed during the day, most prominently during the autumn and spring periods (refer to Section 3.2.1). This continues to present challenges to the power system in terms of voltage control, ramping between minimum and maximum demand, frequency control services, system strength, and inertia.

Powerlink has contracted a Network Support Agreement with CleanCo Queensland for the provision of Network Support and Control Ancillary Services (NSCAS) for the management and control of voltages. Powerlink has also recently commissioned a new reactor in central Queensland and for voltage control and management during periods of low demand (refer to sections 7.6.2 and 7.7.10 and Table 9.3) and another new reactor is under construction in southern Queensland (refer to Table 9.4).

Powerlink is actively collaborating with Australian Energy Market Operator (AEMO) and participating in national industry working groups to develop strategies and implement measures to address the technical challenges and issues associated with changing grid demand profiles including minimum demand (refer to Appendix B).

2.8 System strength

System strength is a measure of the ability of the power system to remain stable by maintaining the voltage waveform at any given location. The power system is required to remain stable for both normal operating conditions and following system events and disturbances to the power system. System strength has traditionally been provided through energy dispatch and the electrical characteristics of coal, gas-fired and hydro-electric power generation (synchronous generation) which are electrically coupled to the power system. However, many non-synchronous generation technologies, such as large-scale solar and wind, do not inherently provide system strength due to the use of grid-following inverters.

Given the scale of the energy transformation, rapid uptake of VRE resources, and changing synchronous generation operation, it is critical to plan for and procure in advance alternate solutions to address system strength needs to ensure the power system remains secure. As the System Strength Service Provider (SSSP) for Queensland, Powerlink is required to plan and make services available to meet minimum and efficient levels of system strength.

The establishment of the SuperGrid transmission backbone and new PHES facilities detailed within the QEJP will support an increase in system strength across the network. However, these developments are not projected to be fully operational until the early to mid-2030s, and there are expected to be periods prior to this time where minimum system strength gaps may occur.

It is expected that non-network solutions will play an important role in the provision of system strength services to support the energy transformation, including existing and planned PHES solutions, grid-forming BESS, synchronous generation, and synchronous condensers. The optimum mix of technologies is expected to change over time alongside the accelerating development of new technologies and facilities.

Powerlink has completed consultation processes to address an immediate system strength gap within Queensland and entered into a non-network solution with Ratch Australia Corporation to enable Townsville Power Station to operate in synchronous condenser mode where required. Powerlink is also progressing a Regulatory Investment Test for Transmission (RIT-T) consultation to identify network and non-network solutions to address minimum and efficient requirements for system strength until the early 2030s.

Further information on system strength planning and activities currently being undertaken by Powerlink are detailed within Chapter 4 and Section 6.6.2.

2.9 Increasing capacity of the transmission system

Given the step change in the energy landscape, Powerlink is at the forefront of implementing new approaches and technologies and guiding and shaping developments in the market to increase the capability and performance of the transmission system.

Powerlink is continuing to develop the Wide Area Monitoring Protection and Control (WAMPAC) platform to maximise the capability of the network and provide an additional layer of security and resilience to system disturbances and events. WAMPAC rapidly detects specific conditions over geographically diverse transmission assets and initiates appropriate action to adapt to system conditions such as changing the network configuration or altering generation and load characteristics. Its speed enables the platform to be effective in sub-second timeframes and can remediate dynamic conditions to secure the network and avoid adverse operating conditions.

WAMPAC has been implemented for system protection services across the Central Queensland to South Queensland (CQ-SQ) grid section. Further applications for the technology are progressing in north Queensland to more effectively manage and operate the transmission network during outages. It is also anticipated that WAMPAC will be instrumental in increasing the hosting capacity of REZs and mitigating the impacts of network contingencies and planned outages within the SuperGrid transmission backbone in the future (refer to sections 6.12.2 and 7.3).

Powerlink is implementing new technology to optimise the performance and capacity of the high voltage network to enable the energy transformation. Detailed assessments have been completed for the adoption of advanced conductor technology, and Powerlink anticipates utilising this technology within 275kV transmission infrastructure in central and south Queensland to increase the thermal ratings of transmission lines and maximise REZ hosting capacity.

Powerlink has commenced field trials of equipment to enable real time ratings for overhead conductor to increase the thermal capability of the transmission network during times of elevated wind speeds. Artificial intelligence (AI) techniques and tools are also being investigated by Powerlink to help optimise the operation and performance of the high voltage system.

2.10 Other initiatives

In coming years there will be significant changes in transmission flow patterns as coal generators are progressively withdrawn or change their operational dispatch patterns, new sources of generation and storage are developed, and as the loads change in quantum, shape and distribution. Matters such as marginal loss factors, network charges, and transmission congestion are all sensitive to these changes, and proponents are encouraged to take these into consideration when making decisions on future investments. Powerlink has developed a Fact Sheet available on its website to help proponents understand the possible effects of changes in transmission flow patterns.

Powerlink has continued its close collaboration with the Australian Bureau of Meteorology over the past year undertaking joint analysis into the characteristics of the renewable resources throughout the State. These important insights will help Powerlink better understand weather changes and intermittency and develop the network to progress the energy transformation as seamlessly as possible.

AEMO has designated a number of transmission infrastructure projects as actionable within the 2024 Integrated System Plan (ISP). These projects are located in central and south Queensland and include an upgrade to the transfer capacity across Queensland to New South Wales Interconnector (QNI). Powerlink is progressing these projects through a range of planning and consultation activities and continues to collaborate closely with AEMO on transmission planning through technical working groups and other related activities (refer to Appendix B).

Powerlink opened the Gladstone SuperGrid Training Centre and Transmission Hub in 2023. The centre will support the development of important skills that will be needed to enable the energy transformation. A range of roles will be located at the hubs including community relations, cultural heritage relations, project management, field staff, health and safety officers, training personnel, engineers, support services staff, and trades people to provide local communication, engagement, construction management, and engineering field support.

Powerlink has also established a new office for CopperString 2032 in Townsville. The office will be colocated with a new SuperGrid Training Centre and Transmission Hub, and will provide services including community relations and support, cultural heritage relations, and project management. The training hub will provide specialist high voltage skills to build, operate and maintain the northern parts of the SuperGrid transmission network including CopperString 2032.

2.11 Community engagement and benefits

There is a significant amount of new transmission infrastructure that is needed to be built as part of the energy transformation. Powerlink recognises that regional communities play an important role in hosting the essential infrastructure necessary to support the energy transition. Through these activities, there is also potential to create sustainable and legacy opportunities for regional Queensland, and Powerlink will continue to work closely with communities to identify and deliver benefits in these areas.

Powerlink's Community Engagement Strategy drives early and authentic engagement to listen to landholders and communities to better understand their needs and priorities. The main goal is to develop co-existence arrangements with landholders and seek to provide long-term benefits for the communities in which we operate.

In 2023, Powerlink announced a new framework that significantly boosts payments to landholders hosting new transmission infrastructure. The SuperGrid Landholder Payment Framework provides higher payments for Queensland landholders that host new transmission infrastructure. The new framework now provides increased flexibility with landholders able to choose upfront or on-going annual payments. Powerlink also became the first transmission company in Australia to offer payments to landholders with properties adjacent to new transmission infrastructure.

Powerlink's Community Investment Framework ensures local benefits and community investment go hand in hand with delivering Queensland's new energy future. A key pillar is the new SuperGrid Telecommunications Program. As part of this program Powerlink will work with its subsidiary QCN to boost internet connectivity and mobile coverage in regional communities hosting SuperGrid infrastructure and REZs. High-speed internet can be supplied using fibre optic cables installed within overhead earthwires on top of new transmission infrastructure.

The development of new transmission infrastructure within regional areas will also provide additional benefits including new employment and jobs opportunities. The Queensland Government and Powerlink aim to source material and labour requirements to enable the energy transformation from locally produced sources and manufacturers where practical.

2.12 On-going transformation

Along with opportunities, the power system of the future will present operational, planning, regulatory and market challenges. New frameworks, strategies and infrastructure are being developed and implemented to enable an efficient and orderly transformation of the energy system to achieve net zero emissions.

The QEJP underpinned by the Infrastructure Blueprint provides a roadmap to a decarbonised energy future, and Powerlink is actively progressing key activities to transform the energy system to one underpinned by clean, sustainable, cost effective, and reliable energy supply.