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 supply.

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 carbon future.
- Powerlink has worked 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 for the power system. Powerlink continues to inform and provide context to broader technical aspects associated with the energy transformation.
- Powerlink's long-term strategic planning considers a staged approach of 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 carbon 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 network evolves.

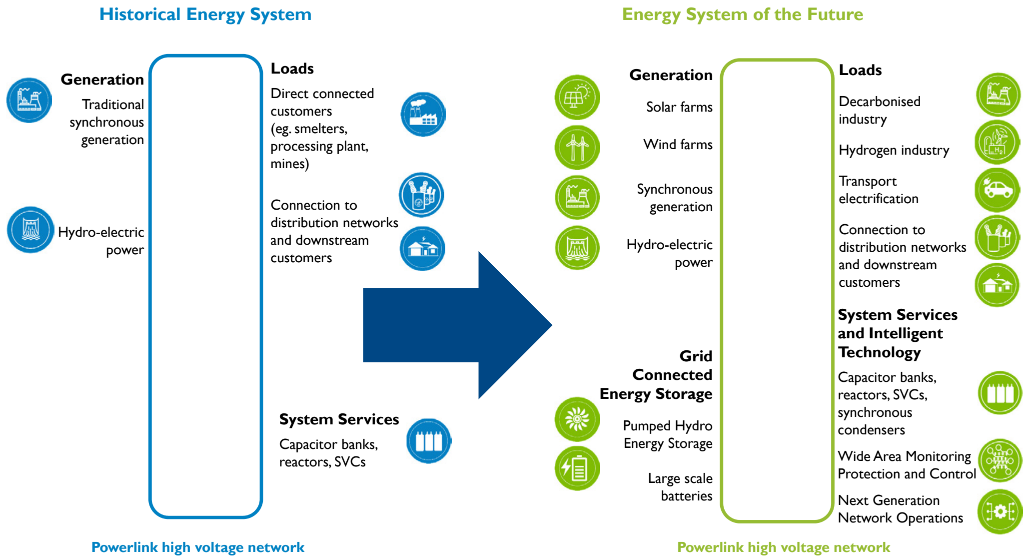
2.1 Introduction

The transformation of the energy system within Queensland to one underpinned by clean, sustainable and affordable renewable energy is well underway. This is prevalent with an increasing share of large-scale VRE within the state and continued strong growth in the uptake of rooftop PV systems. 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. A new industry based on hydrogen is also emerging.

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 hydrogen markets, consumer energy sources, and intelligent control and orchestration being integral components of the decarbonised energy system (refer 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. Since publication of the QEJP in September 2022 and 2022 Transmission Annual Planning Report (TAPR), Powerlink has contined to work closely with the Queensland Government providing technical insights on transmission network development for optimal pathways to 80% renewables by 2035 and net zero emissions.

Figure 2.1 Energy system of the future



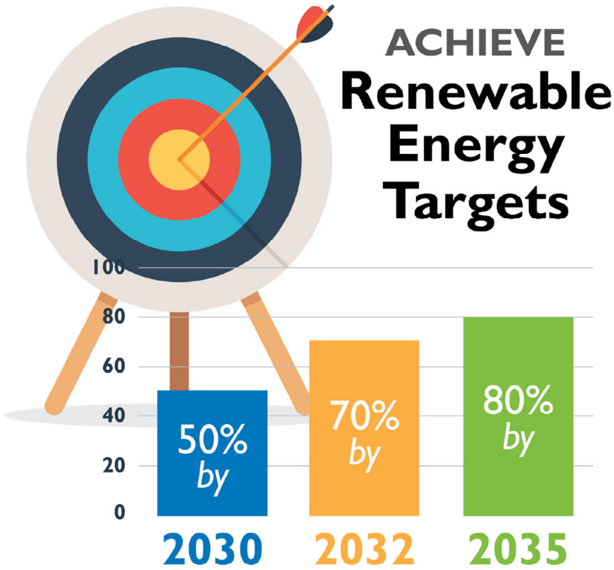
2.2 Queensland Energy and Jobs Plan

The QEJP sets out the roadmap for the transformation of the energy system, and adds to Queensland's existing renewable energy target of 50% by 2030 with new targets of 70% by 2032 and 80% by 2035 (refer Figure 2.2). The plan also details a range of initiatives and foundational investments to achieve these targets.

The Queensland SuperGrid Infrastructure Blueprint ("Infrastructure Blueprint") was published in conjunction with the QEJP. The Infrastructure Blueprint outlines the Optimal Infrastructure Pathway (OIP) to deliver a clean, reliable and affordable electricity system.Powerlink continues to inform and provide context to the broader technical aspects associated with the energy transformation. In November 2022, Powerlink published a report on Actioning the Queensland Energy and Jobs Plan. This document outlines initiatives and steps that Powerlink intends to undertake to enable the QEJP.

The Queensland SuperGrid Infrastructure Blueprint is a point in time plan. Powerlink continues to monitor the underlying assumptions forming the Infrastructure Blueprint, and test future scenarios as the market evolves and the quality of available information improves as part of detailed design and planning phases. The Infrastructure Blueprint will be updated every two years with the OIP to reflect new infrastructure investments, changing market conditions, and the market outlook.

Figure 2.2 Queensland renewable energy targets[1]



2.3 The Queensland SuperGrid transmission backbone

The Queensland SuperGrid detailed within the Infrastructure Blueprint includes a number of inter-related elements spanning renewable generation, firming of the intermittent generation, and the transmission network to connect this all together.

A key part of the OIP transmission infrastructure detailed within the Infrastructure Blueprint is a new high-capacity transmission backbone to enable large-scale efficient transportation of renewable energy and storage across the state. The SuperGrid transmission backbone has four stages of development to provide connection capacity for new PHES facilities and access to Queensland's high quality renewable energy resources. These stages comprise of the following:

- Stage 1 – Borumba Connections
- Stage 2 – Central Queensland Connection
- Stage 3 – Pioneer Burdekin PHES and North Queensland Connection
- Stage 4 – Townsville to Hughenden Connection.

Given the capacity requirements, changes in power flows, longer distances and future use, the SuperGrid is proposed to be constructed using 500kV High Voltage Alternating Current (HVAC) technology. The system will be complemented by the use of contemporary and emerging technologies to limit the scale of investment required to deliver the necessary reliability and resilience (refer Section 2.8). For sections of the network with lower load transfer requirements, lower voltages such as 275kV will continue to be most economic and appropriate.

The implementation of 500kV provides a number of benefits compared to the 275kV backbone voltage currently operating within Queensland. These include the requirements for narrower easements and more timely constructability compared to the two or more overhead 275kV transmission lines that would otherwise be required. The use of a 500kV voltage level is also aligned with that used within the New South Wales (NSW) and Victorian networks, and enables the Queensland transmission grid to more readily interconnect with the southern states in the future to access greater shares of geographically diversified renewable generation sources.

Powerlink has also considered High Voltage Direct Current (HVDC) technology for the SuperGrid transmission backbone. HVDC technology is continually evolving and currently has applications including submarine and long distance point-to-point connections. HVDC Voltage Source Converter (VSC) technology also offers a set of beneficial functionalities made possible by sophisticated advancements in control and power electronics located at the converter terminal stations. HVDC is in high demand globally for offshore wind farms and undersea interconnectors, and the technology and costs will be monitored closely as it is deployed around the world. A disadvantage of HVDC is the high cost of converter stations and technical complexity associated with intermediate terminal stations.

[1] Source: Queensland Energy and Jobs Plan Overview.

The proposed SuperGrid transmission backbone will require a number of intermediate stations to integrate into the existing transmission system, marshalling power from renewable sources distributed along its length and de-loading the parallel 275kV network thereby maximising renewable hosting capacity. Following extensive power system modelling and financial modelling, HVAC has been demonstrated to be more cost effective under this network topography for the SuperGrid transmission backbone.

Powerlink is well progressed with preparatory activities for the first stage of the SuperGrid transmission backbone (Borumba PHES connections). Subject to planning approvals, the Borumba PHES is scheduled to be operational circa 2030 and is a cornerstone of Queensland's future clean energy system, providing critical storage and firming for increasing levels of variable renewable generation. With a planned capacity of up to 2GW and 24 hour storage, the proposed Borumba PHES requires a connection to the network that delivers reliability and network security commensurate with the role that Borumba PHES needs to play in the firming the future VRE mix.

The connection architecture for Borumba PHES has been chosen to diversify connection paths and leverage existing and planned network capacity upgrades linked to condition based drivers to maximise network benefits from the connection. There will be two connection paths for Borumba PHES. The first connects to Powerlink's existing substation site located at Halys in south west Queensland, and the second connects to Powerlink's existing substation site at Woolooga.

The Halys Substation connection also provides access to high-quality renewables in south west Queensland to help supply the Borumba pumping load and facilitate strong intra-regional connections with the rest of the National Electricity Market (NEM). The connection to Woolooga Substation allows for increased utilisation of the coastal 275kV Central to Southern Queensland (CQ-SQ) corridor to supply load growth in Southeast Queensland (SEQ) while providing access to future renewable energy developments in the Wide Bay region.

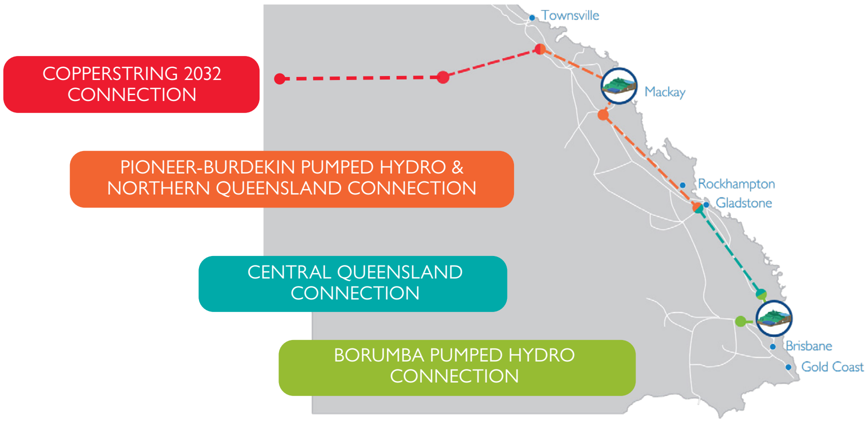
The second stage of the SuperGrid transmission backbone will comprise of high voltage transmission to connect Borumba PHES to the central Queensland REZs and load centres. This connection provides important storage and firming capacity for the area.

The third stage of the SuperGrid transmission backbone is aligned with the establishment of the proposed Pioneer-Burdekin PHES in North Queensland. This involves transmission connections from Townsville to the proposed PHES and onwards to Central Queensland. Powerlink intends to deliver this stage in three parts with the initial connection to the Pioneer-Burdekin PHES before its target commencement of operations during the early to mid-2030s.

The fourth stage of the SuperGrid is the Townsville to Hughenden transmission development. The Queensland Government has reassessed opportunities that a high-capacity transmission network can provide for critical minerals processing and mining areas within the North West Minerals Province (NWMP) and the rich renewables resources available in the Hughenden area.

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 for commissioning from 2029 (refer Section 2.3.1).

Figure 2.3 Queensland SuperGrid transmission backbone



2.3.1 CopperString 2032

The CopperString 2032 project, formerly known as CopperString 2.0, initially involves constructing 840km of high voltage transmission line from Townsville to Mount Isa that will connect the NWMP to the NEM. CopperString 2032 will form an essential part of the Queensland SuperGrid transmission backbone. Powerlink has taken 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, encompassing towns such as Mount Isa and Cloncurry, will provide reliable renewable power to one of the richest deposits in the world of minerals 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.

CopperString 2032 will also enable the connection of significant quantities of renewable energy from north west Queensland to the coastal Queensland transmission backbone. The Hughenden region has the potential to host significant levels of new wind generation which has complementary properties to renewable generation within the rest of the state. The Hughenden region has been designated as Flinders REZ within the draft Queensland Government REZ Roadmap (refer Section 2.4.2).

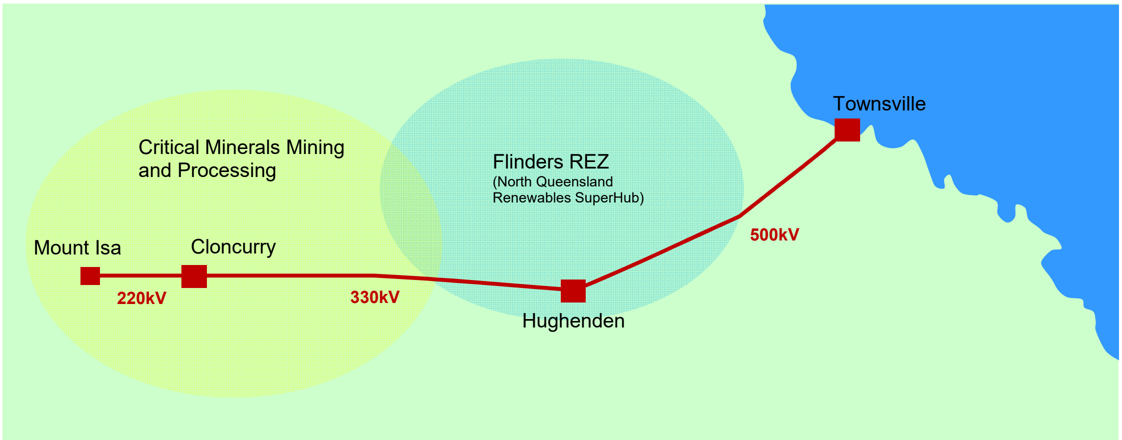
CopperString 2032 will have a higher transmission capacity than the previously announced CopperString 2.0. The transmission line from Townsville to Hughenden is planned to be constructed at 500kV which will enable higher levels of hosting for renewable energy.

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

- Construction of new 500kV double circuit transmission line from Townsville to Hughenden
- 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 Hughenden Substation following the CopperString 2032 project.

Figure 2.4 CopperString 2032 transmission development



Powerlink is currently progressing early works for CopperString 2032 ahead of construction commencing in 2024. Powerlink has commenced field and geo-technical investigations, cultural heritage and ecological surveys, transmission line designs, statutory approvals, and engagement with landholders, communities and other key stakeholders.

Due to the size and scope of CopperString 2032, the project will be broken down into several work fronts with construction occurring in multiple locations at the same time to ensure safe travel distances for workers and timely project delivery. Powerlink anticipates that CopperString 2032 will be commissioned during 2029.

The Australian Energy Market Operator (AEMO) has included CopperString 2032 project as an Anticipated Project within the recently published AEMO 2023 Transmission Expansion Options Report.

2.4 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 to the transmission network. 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 coordinated manner, 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 coordination 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 whilst reducing investment risk and financing cost for developers.

The Queensland Government has undertaken a range of initiatives to make the connection process for renewable energy proponents to REZs smoother and simpler, and for establishing on-going benefits for landholders, communities, and regional areas. Powerlink has worked closely with the Queensland Government on these initiatives which are outlined below and within Section 2.9.

2.4.1 Renewable Energy Zone Roadmap

The Queensland Government published the draft 2023 Queensland REZ Roadmap in June this year. The Roadmap outlines the pathway for connecting 22GW of additional 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 coordination.

Powerlink has provided significant input to developing the draft 2023 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. These indicative REZ locations have been identified based on analysis of a range of factors. As Queensland's JPB, 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 (2022-2024) - Building strong foundations
- Phase 2 (2024-2028) - Scaling and expanding opportunities
- Phase 3 (2028-2035) - Preparing for net zero by 2050.

The three phases take into account the sequencing of other large-scale energy infrastructure developments including the SuperGrid transmission backbone, and the Borumba and Pioneer-Burdekin 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 REZs may also be identified in future to meet growing demand from green hydrogen, decarbonisation, electrification of existing industrial processes, and other load developments. It is anticipated that the REZ Roadmap will be updated every two years and aligned with the Infrastructure Blueprint to reflect latest market outlook and developments.

2.4.2 Potential Queensland Renewable Energy Zones

As detailed in the draft 2023 Queensland REZ Roadmap, a framework is being developed across the development stages for engagement with communities, landholders, First Nations Peoples, and key stakeholders to inform the rollout of REZ across the state. This includes REZ Roadmap consultation, REZ Delivery Body REZ Management Plan planning activities, and the establishment of and engagement with Regional Energy Reference Groups throughout the project lifecycle.

The 12 potential REZs noted in Section 4.2.1 are outlined below within their respective regions. Further details are provided 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 also in proximity to the planned development of the Pioneer-Burdekin PHES and emerging hydrogen hubs within Townsville and the Bowen regions. Powerlink is also establishing a new transmission and training hub in Townsville to provide local engineering and field services to support the transmission network in North Queensland (refer Section 2.8).

There is currently one in-flight REZ under construction in Far North Queensland. This REZ is scheduled for completion by April 2024 (refer Table 9.3). In-flight REZs are renewable energy developments that are already progressing under the existing NER and may be converted to declared REZs in the future.

Two additional REZs are earmarked for this area. The Collinsville and Flinders REZs are anticipated to provide up to 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 decarbonisation and electrification of industrial and metals processing facilities and the emergence of new hydrogen hubs 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, and are anticipated to provide more than 4GW of combined hosting capacity. Powerlink is currently progressing planning activities for new transmission infrastructure to enable these REZs (refer Section 8.2.3).

The Isaac and Capricorn REZs are anticipated to form the second stage of REZ development, and provide 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. Renewable energy resources within 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 in-flight REZs for South Queensland. The Southern Downs and Western Downs REZs are expected to have a combined network hosting capacity exceeding 4GW. Powerlink is providing transmission capacity to enable these REZs through the construction of dedicated 275kV transmission lines to several wind developments in the area.

Powerlink has also completed preparatory activities set out in AEMO's 2022 Integrated System Plan (ISP) for increasing the transfer capacity of the transmission network from south west to south east Queensland, and increasing the hosting capacity of renewable energy in south west Queensland (refer to Section 6.15).

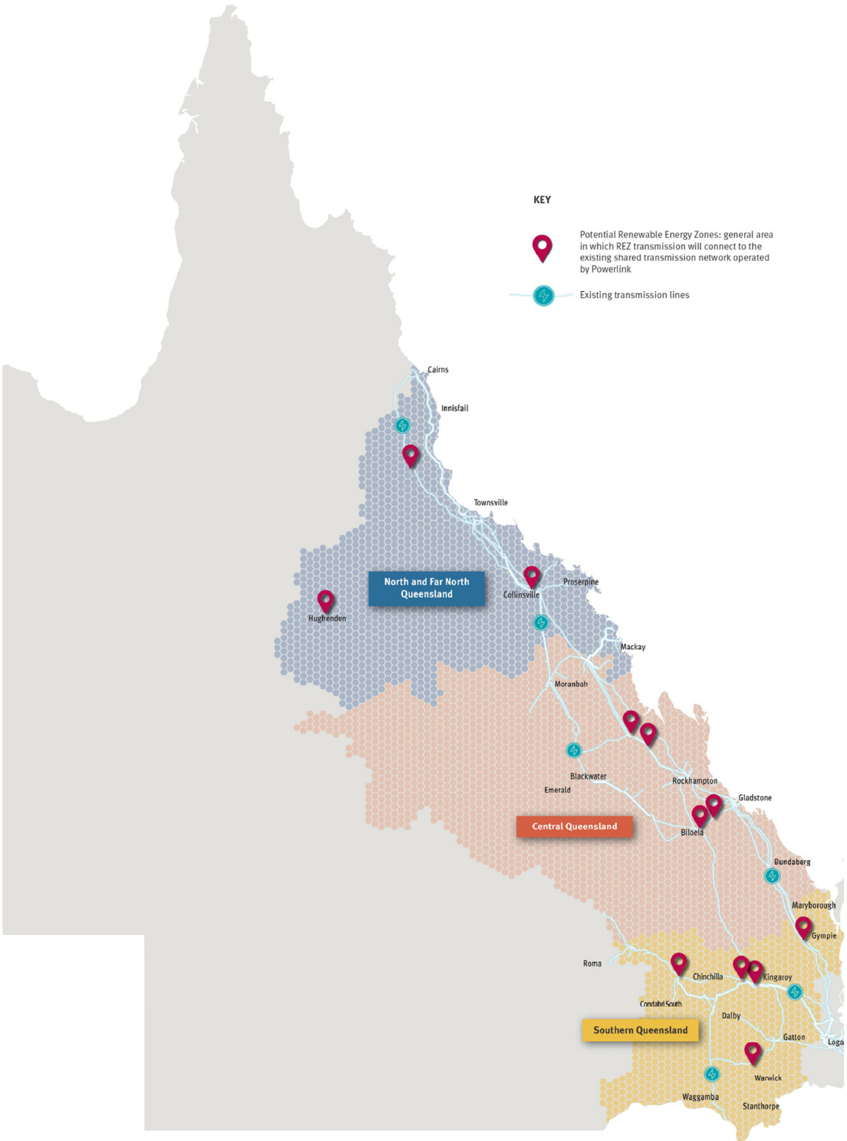
There are three additional REZs proposed for south Queensland. The Woolooga and Darling Downs REZs form part of the second stage of REZ development within the Roadmap, and are expected to provide around 4GW of combined hosting capacity. The Tarong REZ forms part of the third stage of REZ development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

Table 2.1 Expected REZ installed generation within the draft 2023 Queensland REZ Roadmap[2]

Region	REZ	Expected installed generation	In-flight	Phase 1	Phase 2	Phase 3
Far North and North Queensland	Far North Queensland	500 to 700MW	✓			
	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	✓			
	Western Downs	2000 to 2600MW	✓			
	Woolooga	1600 to 2000MW			✓	
	Darling Downs	1600 to 2000MW			✓	
	Tarong	2000 to 2400MW				✓

2 Source: Draft 2023 Queensland Government REZ Roadmap.

Figure 2.5 Potential REZs outlined within the draft 2023 Queensland Government REZ Roadmap[3]



2.4.3 Delivery of Renewable Energy Zones

There are two distinct roles in Queensland REZ delivery under the draft Queensland Government Energy (Renewable Transformation and Jobs) Bill.

The first role is the function of REZ Delivery Body (RDB). The RDB would be responsible for providing advice on proposed REZ to government, developing draft and final REZ Management Plans (RMP) for each REZ to enable the declaration of the REZ, and consulting with community.

The second role would involve Powerlink performing the function of the REZ Transmission Network Service Provider. This role would be responsible for planning, design, owning, constructing, operating and maintaining REZ transmission infrastructure, and undertaking processes for the connection of renewable generation projects to the REZ.

3 Queensland Government REZ Roadmap.

2.5 Energy storage and firming

Energy storage and firming services will form an integral part of the future mix of technologies in Queensland. These 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, consumer demand, and other factors. The energy system of the future will require a mix of firming services ranging from PHES, large-scale grid-connected BESS, community battery systems, residential household batteries, and dispatchable generation sources (such as generation fuelled by natural gas, hydrogen or renewable fuels).

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 over shorter periods. Both technologies will provide critical system security services necessary to support the power system as part of the energy transformation.

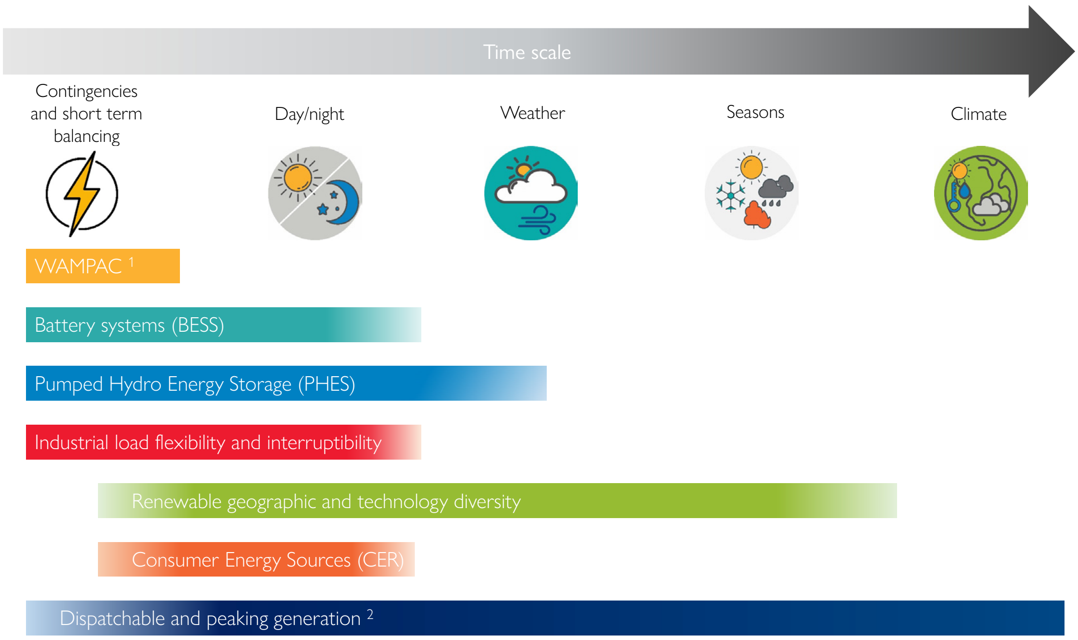
The nature and mix of energy firming services within Queensland will be required to operate across a range of time scales and operating conditions to ensure reliability of supply. These operating horizons range from very short response periods (e.g. such as those during network contingencies) to longer periods across seasons and multi-year periods reflecting climate variations. Potential technologies which are likely to play an integral role in firming across the range of time scales are outlined in Figure 2.6.

The optimal mix of technologies involves an economic trade-off. Non-weather dependent or energy-limited generation sources (such as gas or potential hydrogen or renewable fuelled generating stations) are likely to play an important role to address extremities in weather and climatic conditions. Another important aspect involves pursuing 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.

There are also increasing drivers for large-scale electrified industrial processes to be capable of operating more flexibly to take advantage of wholesale market pool prices when there may be an abundance or scarcity of renewable generation. There is currently limited demand side participation and management within the Queensland energy system, however, this is expected to increase as more industrial processes transform to electrified operation, and new green hydrogen and other decarbonised facilities are established.

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

Figure 2.6 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 2.8.

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

2.5.1 Pumped Hydro Energy Storage

The QEJP details the investment of two publicly owned long-duration PHES facilities. These large-scale deep storage facilities will be cornerstone infrastructure development for the energy transformation and moving to 80% renewable energy by 2035. Subject to planning approvals, the two facilities comprise the Borumba PHES located south west of Gympie and the Pioneer-Burdekin PHES located within North Queensland near Mackay.

Borumba PHES

The Borumba PHES was selected as the first site for development following a state-wide assessment of potential pumped hydro locations across the state. 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.

Previously Powerlink had been conducting a range of detailed design, business case development, and other preparatory activities for the Borumba PHES. In November 2022, the Queensland Government established a new publicly owned entity (Queensland Hydro) to design, deliver, operate and maintain long duration pumped hydro storage assets for the energy transformation. Queensland Hydro has now taken on further works, environmental impact assessments, detailed engineering, geo-technical testing, civil infrastructure upgrades, and other delivery activities for Borumba PHES.

Powerlink has been engaged by Queensland Hydro to develop potential transmission line corridors to connect Borumba PHES to the existing electricity transmission network. Due to the potential generation and storage capacity of the Borumba Pumped Hydro Project, new transmission infrastructure will be needed from the proposed pumped hydro facility at Lake Borumba to Halys Substation in the south-west part of Powerlink's network, and to Woolooga Substation to the north of the proposed facility. The Borumba PHES and associated connections will form part of the Queensland SuperGrid transmission backbone providing long duration deep firming services 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 Pioneer-Burdekin PHES is anticipated to have an energy storage capacity of up to 5GW over 24 hours, with the facility scheduled to commence operations circa 2032. The PHES will form a foundational component of the SuperGrid transmission backbone enabling large-scale transportation and firming for renewable energy to support the decarbonisation and electrification of existing industrial processes, and enable the development of new green hydrogen and other manufacturing industries.

Queensland Hydro will carry out detailed analytical studies to refine knowledge of pumped hydro potential between the proposed upper reservoirs in the Burdekin catchment, and the lower reservoir proposed in the Pioneer Valley near Netherdale. Studies will also include geotechnical investigations, environmental, social and cultural heritage assessments.

Other PHES developments

Powerlink has also been engaged by Genex Power Limited (Genex) to undertake a range of activities relating to 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) currently scheduled for completion during 2024 (refer Table 9.2).

In addition to the above, there are numerous other PHES projects being proposed by the private sector. These proposals will also form important components of the Queensland energy transformation.

2.5.2 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 future network augmentations. Furthermore, 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.

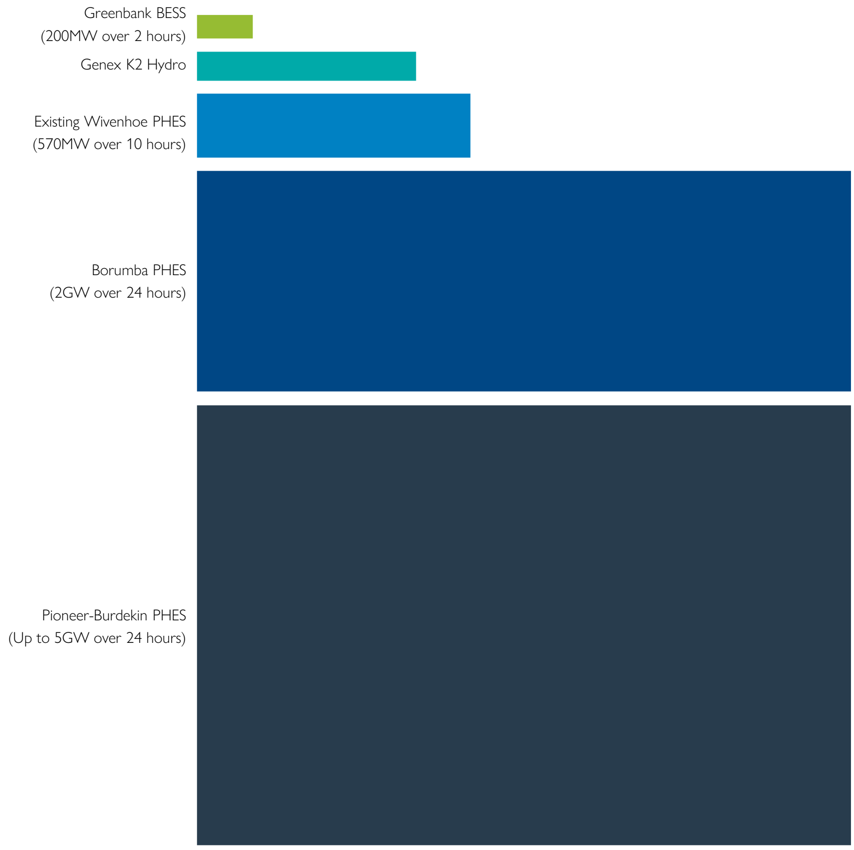
Queensland's first large-scale BESS (100MW/150MWh) was connected to Powerlink's transmission network at Wandoan South Substation in August 2022. A second large-scale BESS built by Genex Power (50MW/100MWh) connected to Powerlink's transmission network at Bouldercombe substation near Rockhampton, commencing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

A number of additional large-scale grid connected BESS are in advanced stages of construction, and are expected to be operational over the near term. These include Powerlink connections for the Western Downs BESS (200MW/400MWh), Greenbank BESS (200MW/400MWh) and Chinchilla BESS (100MW/200MWh) in southern Queensland. Powerlink has experienced continued strong interest in BESS installations across the state.

2.5.3 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 2.7. PHES and BESS are also able to provide a range of transmission and system security services, including system strength, inertia, frequency and ancillary control. These services are critical for the secure operation of a decarbonised energy system.

Figure 2.7 Relative energy storage capacities of PHES and BESS



2.6 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 secure, cost effective and reliable transmission network will be pivotal in enabling sectors the opportunity to electrify operations with renewable generation sources, and for Queensland to transform into a renewable energy exporter.

The electrification of existing fossil fuel operation 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.

2.6.1 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 zones, and electrification of mining operations will impact on transmission capacity requirements to these areas (refer to sections 8.2.1 and 8.2.2). 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 in transmission capacity with demand potentially exceeding several giggawatts ramping over time from the 2030s. These developments also have the potential to significantly alter energy flow patterns and power transfer capability requirements across Powerlink's high voltage network.

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 the design of the high voltage transmission network and firming resources to support the energy transformation.

The transportation sector presents one of the largest opportunities for decarbonisation. The adoption of electric vehicles (EVs) presents the shortest term opportunity for increasing electrification and decarbonisation. The charging behaviour and patterns for EVs has the potential to either support or challenge network requirements from the grid. The management of EV charging will be important to optimising the utilisation of the existing network, particularly within the Moreton and Gold Coast zones.

EVs have the potential for dual purpose application in terms of being both mobility and household distributed energy sources. EV battery capacities are generally larger than required for typical household daily use, and over time it may be possible to leverage this capacity to smooth daily demand usage patterns and rooftop PV output. Both residential battery systems and EVs have the potential to optimise transmission and distribution network utilisation under appropriately designed orchestration incentives and mechanisms.

Powerlink, Energy Queensland and the Queensland Government recognise the need to ensure that investments and measures to address minimum demand are complementary, and that energy storage across the supply chain (transmission, distribution and consumer level) need to operate in a coordinated manner. Orchestration of technologies across the different supply chain levels, including large-scale generation and storage, demand side management (DSM) and time of day shifting, customer energy and storage resources, will be key to optimising utilisation and performance of the energy system.

2.6.2 Emerging hydrogen industry

The Queensland Government 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, Gladstone, and Brisbane Trade Coast areas. Potential markets include both domestic hydrogen to decarbonise existing industrial processes and establishment of new hydrogen export markets.

Powerlink and the Queensland Government are supporting a range of significant hydrogen development activities in Queensland including the connection of renewable hydrogen facilities within the Brisbane Trade Coast area, and potential connection of green hydrogen and ammonia production facilities in Central and North Queensland.

The Queensland Government is also progressing the establishment of hydrogen hubs. Hydrogen hubs are regions where producers, users and/or exporters of hydrogen are co-located. This lowers infrastructure needs, reduces costs, and supports hydrogen production at scale which helps reduce the price customers will pay for hydrogen. Central Queensland has been identified as a potential hydrogen hub because of the availability of:

- sufficient land, electricity transmission, gas infrastructure and port capacity to meet international export and local industry demand
- skilled workforce and investment environment which supports innovation
- state development area that supports the development of industrial hubs, infrastructure corridors and major development sites
- proximity to REZs (including the Callide and Calliope REZs).

2.6.3 Rooftop photovoltaic systems

The uptake of rooftop PV systems within both residential and commercial premises in Queensland continues to be strong. There is now over 5.5GW of household rooftop systems connected to the network (refer Section 3.2.1).

The uptake and development of distribution network connected 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. This continues to present challenges relating to voltage control, ramping between minimum and maximum demand, frequency control services, system strength, and inertia.

Powerlink has completed regulatory consultation processes to address voltage control within South East Queensland during periods of minimum demand (refer to Section 6.6). Powerlink has also entered into a Network Support Agreement with CleanCo Queensland for the provision of network support and control ancillary services (NSCAS) to address an immediate gap for the management and control of voltages.

Powerlink is actively collaborating with AEMO and participating in national industry working groups to develop strategies and implement measures to address technical challenges associated with the changing grid demand profile (refer to Appendix B).

2.7 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, both with and without the occurrence of an event or disturbance or fluctuations in supply or demand. System strength has traditionally been provided through energy dispatch by 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 use of grid-following power electronics technology to generate electricity.

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 levels across the network. However, these developments are not projected to be fully operational until the early 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 contribute to the provision of system strength 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 also expected to change over time alongside the accelerating development of new technologies.

Further information on system strength planning and activities currently being undertaken by Powerlink are detailed within Chapter 4 and Section 6.8.2.

2.8 Other initiatives

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 optimise performance and utilisation of the transmission system.

Powerlink is progressively implementing the Wide Area Monitoring Protection and Control (WAMPAC) platform to maximise the utilisation 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 or load characteristics of connections. 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 CQ-SQ grid section (refer to Section 7.3), and further applications for the technology are progressing to more effectively manage the performance of the transmission network. 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.

Powerlink has also continued to collaborate closely with AEMO on transmission expansion options for the 2024 ISP through technical working groups and other related activities. Powerlink has completed preparatory activities identified within the 2022 ISP (refer Section 6.15).

Powerlink opened the Gladstone SuperGrid Training Centre and Transmission Hub in May 2023. The centre is generating 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 co-located with a new SuperGrid Training Centre and Transmission Hub. The office will provide similar services to the Gladstone Training Centre 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.

2.9 Community engagement and benefits

New transmission infrastructure that is needed to be built as part of the energy transformation has the potential to create long-lasting benefits for Queensland communities. Powerlink will continue to work closely with Queensland communities to deliver benefits for those impacted by energy infrastructure.

Powerlink is undertaking early and authentic engagement to listen to landholders, communities and other stakeholders 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. Powerlink's Community Engagement Strategy underpins this focus on ensuring local benefits and community investment go hand in hand with delivering Queensland's new energy future.

In May 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 increase in payments is based on property-specific values and impacts, as opposed to using a flat rate. Powerlink also became the first transmission company in Australia to offer payments to landholders with properties adjacent to 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.

Powerlink is also working with its subsidiary QCN on how best to connect regional townships and areas within Queensland with high-speed internet using fibre optic cables installed within overhead earthwires on top of transmission infrastructure.

2.10 On-going transformation

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

The Queensland Energy and Jobs Plan 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, resilient and reliable energy supply.