CLIMATE ENERGY FINANCE

Queensland's Energy Transformation: From Coal Colossus to Renewable Energy Superpower

An analysis of Queensland's current energy grid and its transition from FY24 to FY36, modelling the impacts of large-scale and distributed energy generation and storage to meet Queensland's renewable energy and emissions reduction targets.

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About Climate Energy Finance

Climate Energy Finance (CEF) is an Australian based, philanthropically funded think tank established in 2022 that works pro-bono in the public interest on mobilising capital at the speed and scale needed to accelerate decarbonisation and the energy transition consistent with the climate science.

We conduct research and analyses on global financial issues related to the energy transition from fossil fuels to clean energy, as well as the implications for the Australian economy, with a key focus on the threats and opportunities for Australian investments, regional employment and value-added exports. Beyond Australia, CEF's geographic focus is the greater Asian region as the priority destination for Australian exports, particularly India and China. CEF also examines convergence of technology trends in power, transport, mining and industry in accelerating decarbonisation. CEF is independent, works with partners in the corporate and finance sector, NGOs, government and the climate movement.

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Matt Pollard, Global EV Supply Chain Analyst, focuses on the significant growth opportunities future-facing companies have in the electrified transport and energy transition. He has a Bachelor of Economics from the University of Queensland, majoring in International Trade and Finance. Previously, Matt spent 2 years studying biotechnology, focusing on chemistry and nanotechnology at the University of Queensland. Matt has published a number of reports and op-eds on the energy transition, with a focus on the strategic opportunities for Australia to become a renewable energy powered value-added critical minerals superpower.

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Tim Buckley, CEF's founder, has 35 years of financial market experience covering the Australian, Asian and global equity markets from both a buy and sell side perspective. Before starting CEF as a public interest thinktank in 2022, Tim founded the Australia and Asian arms of the global Institute for Energy Economics and Financial Analysis in 2013 and was Australasian Director until 2022.

Prior to this, Tim was a top-rated equity research analyst over 2 decades, including as head of equity research in Singapore at Deutsche Bank; MD and head of equity research at Citigroup for 17 years; and head of institutional equities at Shaw & Partners. From 2010-2013, Tim was co-MD of Arkx Investment Management, a global listed clean energy investment start-up jointly owned with Westpac Bank. Tim is widely recognised and extensively published as an expert on Australian and international energy transition and the accelerating shift of global capital to decarbonisation, and is a sought after commentator and advisor.

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Important information

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Key Findings

In September 2022, the Queensland Government introduced the transformational Energy and Jobs Plan, a $62bn climate, energy and future industries policy designed to eliminate the state's reliance on fossil fuels.

The Energy and Jobs Plan has created a monumental market signal for the energy transition in our northern state, supported by a 75% by 2035 emissions reduction target, crowding in an unprecedented wave of new investment in renewable generation and storage, and driving the emergence of new-energy industries that have become feasible with a decarbonised grid.

In an incredibly short timeframe, Queensland has pivoted from energy and climate laggard to a national leader in distributed rooftop solar and large-scale firmed renewables and infrastructure.

As cost of living dominates the national conversation, this energy system transformation will deliver lasting savings to households and businesses in Queensland exposed to energy price hyperinflation and volatility driven by our historical reliance on fossil-fuels, even as it enables industry to decarbonise and unlocks Queensland's critical minerals bonanza.

As we demonstrate in this report, QLD is at the precipice of a cleantech revolution, one that well positions the state as a renewable energy and cleantech superpower.

The decarbonisation of Queensland's energy grid also has wider implications: it is critical to achieving national emissions reduction and renewables targets, and a key enabler of Federal ambition.

1. QUEENSLAND IS ON TRACK TO EXCEED ITS RENEWABLE ENERGY TARGETS AS CLEAN ENERGY REPLACES COAL

In 2022, the Australian government legislated its greenhouse gas (GHG) emissions reduction target of 43% by 2030 relative to 2005, net zero by 2050, and a renewable energy target of 82% by 2030.

QLD has committed to a 30% reduction in emissions by 2030 on 2005 levels. In February 2024, the Government introduced a bill to legislate a 75% reduction by 2035 and net zero by 2050.

As part of its Energy and Jobs Plan (QEJP), it legislated 70% renewable energy by 2032 and 80% by 2035, earmarking over 25 gigawatts (GW) of new and existing zero-emissions power generation. Current progress indicates it is on track to exceed this target.

QLD's emissions from energy and fuel combustion grew by >14% in 2005-21, comprising >67% of QLD's total emissions. Of that >33% of emissions were from the public electricity sector,[1] showing the key role of the electricity sector transition in

[1] QLD Government, QLD's Greenhouse Gas Emissions and Targets, 19 December 2023

emissions reduction. Whilst the decarbonisation of the state's electricity grid is a critical pillar to achieving the new emissions reduction target, the electrification of refined petroleum used in mining, agriculture and transport is vital to realising QLD's emissions reduction ambition.

Electricity demand and mix – In 2023, 65.8 terawatt-hours (TWh) of electricity was consumed in Queensland, representing 31% of National Energy Market (NEM) demand.

Under the Australian Energy Market Operator's (AEMO) Step Change Scenario[2], QLD demand will grow from 52TWh in financial year (FY) 2023 to 89TWh in FY36.

To achieve QLD's ambition of 80% renewables by 2035, renewable energy must supply ~69TWh in FY35. This means from renewable penetration of 25% in FY23, renewables must grow at a compound annual growth rate (CAGR) of 13.3% through to FY36.

In FY23, QLD renewables generation grew 26% year-on-year (yoy). Renewables have a CAGR of 37% over the past 5-years, well on track to achieve renewable energy targets.

Coal's decline – **Queensland retains the highest coal penetration state in Australia with coal power accounting for 69% of state demand in 2023. However, financial flows are shifting into firmed renewables at incredible speed and scale.** With renewables the fastest growing energy sources in QLD's grid, the coal colossus of old is in terminal decline, with **QLD's entire government coal fleet set to retire by FY35**.

Given the pace of renewable deployment since the introduction of the QEJP, AEMO now forecasts QLD's coal plants will spend a significantly higher proportion of time at minimum load in FY30, some ~40% compared to today's 10%. Declining capacity factors compromise coal's economic viability, potentially accelerating plant closure schedules.

Given the public ownership of retiring thermal generation, and the 54% minimum public ownership of generation assets under the Energy (Renewable Transformation and Jobs) Bill 2023, the QLD Government has a comparative advantage to the privatisation of these assets in NSW and Victoria. This better enables QLD execution of a smooth transition to firmed renewables whilst managing the impact on grid security and reliability.

Renewables replace coal – QLD's Energy and Jobs Plan forecasts that 24GW of renewable capacity by 2035 is required to replace the 8GW of retiring coal capacity and ensure a stable and reliable growing grid. By 2050, AEMO forecasts ~46GW of new utility-scale wind and solar will be required to replace all fossil fuel generation and retiring capacity of early variable renewable energy (VRE) projects across QLD.

With 9 Renewable Energy Zones (REZ) planned across QLD, AEMO estimates this 46GW will be met and exceeded, flagging a renewables potential of over 50GW of solar capacity and over 42GW of wind capacity. Already, AEMO's Generation Information pipeline now exceeds **41GW of new projects across QLD.**[3]

[2] Step Change is the AEMO's 'central scenario', which assumes the national decarbonisation reduction target of 43% is met, alongside moderate economic growth and high uptake of rooftop solar, batteries and EVs. It is assessed as the most likely scenario. Step Change is aligned with the International Energy Agency's (IEA) Sustainable Development Scenario (SDS).

[3] AEMO, Generation Information October 2023, 2 November 2023

2. FIRMED RENEWABLES ARE THE CHEAPEST ENERGY & QUEENSLAND LEADS THE WAY

Renewables are deflationary. The price for installing rooftop solar PV in Queensland has declined by 54% in the past decade. Lithium-ion cells, used in batteries of EVs and stationary storage systems, have seen volume-weighted costs fall by over 90% over the same timeframe.

QLD's transformation over the last 20 years from entirely reliant on coal to a national leader in rooftop renewables, illustrates the momentous shift in its energy system.

The marginal cost of electricity produced from wind and solar is zero. As manufacturing for cleantech scales globally, economies of scale are enhanced and unit costs deflate as efficiency improves. Complemented by improving technologies, i.e. improved solar cell and module efficiency and battery energy density, we expect the capital cost of firmed renewables will continue to fall.

By contrast, the traditional fossil-fuel dependent electricity system is inflationary. The finite nature of thermal coal and methane gas, as well as transportation and high marginal costs associated with generating electricity from thermal coal plants and gas turbines, mean fuel costs inflate as demand grows. As fossil fuel reserve grades continue to decline, unit costs of the extraction and transportation of fuel will further raise prices for consumers, even as we continue to ignore the rising implicit cost of methane and carbon emissions.

The Levelised Cost of Energy[4] for variable renewables, i.e. wind and solar, even accounting for additional costs of integrating into the grid with upgraded transmission and additional storage capacity, is the **lowest cost** of all new-build energy technologies in both 2023 and 2030.[5]

CSIRO's GenCost 2023-24 report highlights that thermal coal is only comparative if generators can deliver a high capacity factor (the share of electricity generated by a plant), source low-cost fuel and be financed at a rate that does not factor in the cost of climate policy risk, despite their high-emissions. As fossil fuels continue their trajectory of hyperinflation and aging capacity, marginal cost of production for fossil fuel generators continues to rise. This is coupled with the disruptive nature of solar, in which large-scale and rooftop generators are driving down demand for coal during the day, causing coal operators to run at minimum load for significantly longer periods of time.

In 2023-24, generation costs accounted for ~56% of the QLD electricity tariff pricing structure. Accordingly, as greater solar and wind resources penetrate into the grid, Queenslanders are expected to get relief from the fossil fuel hyperinflation that caused retail tariff hikes since 2022.

Since the record QLD average wholesale prices of $432/megawatt hour (MWh) in June 2022, driven largely by sanctions on the back of Russia's invasion of Ukraine that led to the convergence of soaring

[4] Levelised Cost of Energy (LCOE) is a comparison metric used to analyse the differences in total unit costs a generator must recover to meet all its costs including a return on investment, fuel costs and different project lives. But it ignores methane and CO_2 costs, and relative firming costs.

[5] CSIRO, GenCost 2023-24 Draft, 20 December 2023

thermal coal demand and supply shortages, wholesale prices have fallen 75% to $107/MWh in December 2023.[6] Over 2023, loosening fuel commodity market dynamics, coupled with reduced exposure to fossil fuel prices with **increased penetration of renewables, have led to QLD quarterly average wholesale prices falling by 38% to $79/MWh in 4QCY23**.

The rapid deployment of large-scale and distributed firmed renewable capacity will continue to reduce QLD's exposure to international fossil fuel price volatility. Simshauser and Miller (2023) forecasts a potential **double digit deflation** of standard and controlled residential tariffs in 2024-25.[7]

As clean energy technology manufacturers continue to scale production, and deployment continues to rise globally, capital costs will further deflate, after two years of global hyperinflation in most construction capex costs, including wind, solar, pumped hydro storage (PHS) and grid transmission, both in Australia and globally, fueled by the up to tenfold increase in methane gas and coal commodity prices. Complemented by new high-voltage orchestrated transmission projects, Queenslanders and Australians will benefit from **strong downward pressure** on energy prices that have driven cost of living inflation.

[6] OpenNEM, Queensland Energy, accessed 30 January 2023

[7] Simshauser & Miller (2023) 'On the impact of targeted and universal electricity concessions policy on fuel poverty in the NEMs Queensland Region', CAEEPR Working Paper No.2023-10. Also accessible via Powerlink, 2023 Transmission Network Forum, 30 November 2023

3. PUBLIC & PRIVATE CAPITAL ARE COLLABORATING TO BENEFIT CONSUMERS & INDUSTRY

Public and private partnerships are becoming increasingly important as the QLD grid undergoes a structural change, shifting away from centralisation towards a decentralised model involving both large-scale and distributed small-scale generation and storage, owned and delivered by government, private capital, retailers and households working in collaboration. This transformation is providing permanent and urgently-needed benefits to consumers and to the environment.

At state level, QLD's state-owned energy companies CleanCo, Stanwell, CS Energy, Powerlink, Energy Queensland and QLD Hydro are investing in new clean energy generation and storage projects, sending the market signals needed to crowd in private investment, and underpin projects with long-term energy offtake agreements that help derisk returns for investors.

Under the introduced Energy (Renewable Transformation and Jobs) Bill 2023, the QEJP aims to construct 25GW of large-scale wind and solar, retaining a minimum 54% share from Government-owned companies (GOCs) for generation assets not used for energy exports. Noting that Queensland does face serious supply chain cost premiums and difficulties for projects in north-west and far north Queensland (FNQ), the 25GW target capacity would result in over **$45bn** of investment into large-scale generation, of which **$21bn** from private capital to ensure majority public market share under the legislation.[8]

[8] Assuming average capital cost estimates from AEMO GenCost 2023-24 of $1.19bn/GW and $2.22bn/GW for solar and wind respectively, but also noting the need to add connection costs from IASR workbook and apply locational cost factor

Through the QEJP, **$19bn will be allocated from the QLD budget** over 4-years from FY24, including $5.5bn to QLD energy entities in 2023-24 alone.[9]

AEMO's Step Change scenario has been calibrated in line with the QEJP, factoring in the investments required to decarbonise existing and forecast energy demand under that scenario. The Step Change scenario fulfills Australia's emission reduction commitments in a growing economy, but does not fully factor in the potentially dramatically increased electricity demand from strong industrial decarbonisation and zero-emission energy exports. Step Change reflects a pace that limits global warming to less than 2°C.[10]

Thus, for Queensland to transform into a renewable energy superpower, significantly more investment will be required across the value chain.

The Plan has created a strong market signal and foundation for future investment. Given the incredible pace of the state's transformation, CEF expects the decarbonisation of export industries will result in significantly more projects entering the development pipeline, bringing in further private capital for large-scale generation projects, as well as a tidal wave of associated investments in battery storage and end-user industries.

From the **41GW** of large-scale solar and onshore wind in AEMO's investment pipeline, and the capital costs of CSIRO's GenCost 2023-24, there is a **conservative $73bn of investment proposals in QLD's wind and solar development pipeline alone.**

premiums from the Aurecon Cost and Technical Parameters Review.

[9] QLD Government, [$19bn to be Invested to Transform QLD into Renewable Energy Powerhouse], 13 June 2023

[10] AEMO, [Draft 2024 ISP], 15 December 2023

Concurrently, QLD is building the orchestrated transmission and distribution networks required to deliver utility-scale solar and wind to businesses and consumers.

Powerlink calculated $7.2bn of public investment into transmission projects critical to realising the QEJP, including the connections of both Borumba and Pioneer-Burdekin PHS projects, as well as the Townsville to Hughenden portion of CopperString 2032.[11]

With the $3.2bn extension of CopperString 2032 from Hughenden to Mt Isa, the QLD Government is expected to invest **$10.4bn into new and upgraded transmission projects**.

At consumer and business level, the incredible growth in the state of rooftop PV, and increased adoption of EVs and behind-the-meter (btm) battery storage – consumer energy resources (CERs) – is providing an immense opportunity to empower households and industries to generate, store, efficiently consume and trade electricity, maximising energy bill savings and decarbonising their energy demand.

Meanwhile, the QLD Government has allocated $1.5bn in further electricity bill relief for QLD households and small businesses to combat cost of living pressures this fiscal year.[12]

[11] Powerlink, [Connecting Queensland's Energy Future], November 2022

[12] QLD Government, [$19bn to be Invested to Transform QLD into Renewable Energy Powerhouse], 13 June 2023

4. "SECTOR COUPLING" COULD UNLOCK A WALL OF NEW CLEAN INVESTMENT

Existing energy-intensive industries in Queensland, including alumina, aluminium and zinc refining, mineral and metal extraction and ammonia production, could provide a significant market signal that demand for clean energy is present and will continue to grow into the future, particularly if a strong price signal can incentivise flexible industry demand responsiveness.

End-users are coupling with generators to de-risk nation-leading projects through long-term power purchasing agreements (PPA), providing revenue certainty and fast-tracking the development pipeline.

Accordingly, the pipeline of massive, utility-scale renewable energy projects set to come online is growing rapidly.

For example, Andrew Forrest's Fortescue Future Industries' (FFI) partnership with Incitec Pivot Ltd (IPL) to transition its ammonia production facility at Gibson Island just outside of Brisbane into a nation-leading green ammonia precinct underpins the development of Bulli Creek Green Energy Hub, targeting up to 2GW of solar and battery storage.

The Aldoga solar farm by Spanish infrastructure leader Acciona in the resources and energy precinct of Gladstone, central Queensland, has a long-term PPA with power provider Stanwell, a key member of the consortium behind the CQ-H2 Green Hydrogen project, Queensland's largest renewable hydrogen project.

Mining giant Rio Tinto has contracted 100% of the output of Upper Calliope, Danish group European Energy's 1.1GW solar farm near Gladstone, set to be the largest solar project in Australia.

5. GAME-CHANGING COPPERSTRING COULD UNLOCK NORTH QUEENSLAND'S RENEWABLES & CRITICAL MINERALS BOOM

The QLD Government has demonstrated ambition through critical infrastructure investment – e.g., orchestrating transmission projects into REZs and connecting the vast potential of North Queensland to the state's energy future via Copperstring. This is triggering a tidal wave of new investment proposals into the industries of the future, the key to pivoting from Queensland's reliance on the export of fossil fuels. It is also a vital tool to unlock the energy transition in rural Australia, and the benefits that flow from this including lower power prices for consumers and industry.

CopperString 2032 is a $5bn QLD government investment into a high-voltage transmission highway connecting Townsville in coastal FNQ to Mount Isa in the far northwest. It is the largest economic development project in North Queensland. Alongside the ~840km of backbone transmission from Townsville to Mount Isa, it includes an additional ~200km of transmission branching to connect new renewable generators.[13]

With up to six new substations and ~2,200 tower structures, CopperString will connect isolated towns currently reliant on high-emission inflationary fossil fuels burning in off-grid power stations to the NEM, delivering clean energy to regional Australians whose work has underpinned the state's export growth for decades. For example, the project will free the mining centre of Mount Isa, which is more than 1,000km away from the nearest connection point to the national grid, from its dependence on electricity

[13] Powerlink, CopperString 2032 Fact Sheet, August 2023

generated locally by 342MW of methane gas turbines and an 88MW solar project.[14] [15]

In addition to enabling current large-scale renewable projects to deliver low-cost energy to Queenslanders, Copperstring also provides the opportunity for isolated communities to invest in rooftop solar and btm battery energy storage that can be connected to the grid.

Critically, CopperString and associated infrastructure is the key to the rapid industrial transformation that will power Queensland's zero-emissions economy this century. It will unlock the **North West Minerals Province** (NWMP), a 375,000km^2 region with one of the world's richest deposits of critical minerals and an estimated value of $500bn**.** The NWMP has abundant cobalt, rare earth, vanadium, graphite and tungsten essential for the production of smartphones, wind turbines, batteries and EVs.[16]

By providing the enabling infrastructure for renewables-powered electricity supply to mining and value-adding in Queensland, CopperString will facilitate the phase-out of high-emission diesel fuel used in the transport and extraction of minerals, as well as the decarbonisation of energy used in refining and manufacture.

CopperString 2032 will also unlock the **Q2 REZ North Queensland Clean Energy Hub** (NQCEH) near Hughenden, ~400km southwest of Townsville. NQCEH has the potential to be the largest renewable energy zone in Queensland, with AEMO's draft 2024 Integrated System Plan (ISP) estimating the REZ has **8GW of large-scale solar potential, and 18.6GW** of wind potential, constrained by the planned 2,200MW network capability.[17] It is already catalysing a wave of new investment into renewable capacity in north Queensland. Within the NQCEH, Spanish giant Iberdrola is developing the massive **$2bn 1GW Mount James Wind Farm**, and in January 2024, Italy's Enel Green Power emerged as the successful bidder for the development of the **1GW Julia Creek Renewables Project**.[18]

CEF recognises the challenges associated with economic development in FNQ, namely the construction and cost premium due to tight labour markets and long supply chain costs. Aurecon's Cost and Technical Parameters Review highlights a 1.8x locational cost premium for Q2 REZ in North QLD, compared to Southeast QLD.[19] This is evident in CopperString 2032's inflation from its original $1.8bn price tag in 2020, to $5bn in 2023.[20] Whilst CopperString's commercial viability has declined given its revised capital estimate,[21] CEF believes this enabling investment by the state government as a strategic necessity in helping achieve the state's climate targets and in supporting development of critical minerals value-adding, a necessary step to transition the state away from its current incumbent fossil fuel export base of coal and liquid natural gas (LNG).

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[14] LinkedIn, Mick de Brenni, 23 January 2023
[15] https://www.statedevelopment.qld.gov.au/news/new-solar-farm-to-supply-mount-isa-mine
[16] QLD Government, What is CopperString 2032 and Why is it Important for Queensland, 14 June 2023

[17] AEMO, Draft ISP 2024 Appendix 3. Renewable Energy Zones, 15 December 2023
[18] Renew Economy, Enel Tapped to Build GW-Scale Solar and Wind Project on QLD's CopperString Line, 15 January 2024
[19] Aurecon, Cost and Technical Parameters Review 2023, 15 December 2023
[20] ABC, QLD Government Buys $5bn CopperString 2.0 to Connect North-west to NEM Grid, 7 March 2023
[21] Fossil fuel lobbyist Australian Energy Council, CopperString 2.0: A look at the numbers, 12 May 2022

Queensland's nation-leading investment into transmission and large-scale renewable energy will crowd-in further investment into generation and storage, reducing reliance on inflationary high-emission fossil fuels, putting downward pressure on household, commercial and industrial energy bills, creating an equitable opportunity for regional Queenslanders to be a part of the energy transition, and driving the decarbonisation of the state's industry and economy as fossil fuels enter structural decline and Queensland pivots to its burgeoning opportunity as a zero-emissions energy, trade and investment leader.

6. CERs ARE FAST, SCALABLE, COST-COMPETITIVE & CRITICAL TO GRID STABILITY & RESILIENCE

Queensland is leading Australia in distributed rooftop PV, with an astonishing 5.9GW across > 1 million rooftops (for comparison the total installed capacity of the NEM is 64GW).

Leveraging rooftop solar to develop distributed networks of co-located renewable generation and storage in the community is critical to reducing the risk of centralised NEM failures, as demonstrated again by the massive February 2024 outage at Victoria's end-of-life Loy Yang A coal power station that impacted 30% of the state.

In the 10-years to FY23, rooftop solar generation grew at 21% CAGR, contributing 11.4% of state demand in FY23. The cost of installing solar in QLD has fallen 54% over the last decade.

Only 14,600 rooftop solar systems in QLD have concurrent battery storage, an attachment rate of just 1.45%. Co-located distributed solar and storage is critical to achieving state and federal renewables and emissions targets and ensuring energy system resilience. Incentives are key to accelerate uptake. **CEF applauds Queensland's leadership in establishing the new Battery Booster program this month, providing up to $4,000 rebates to households to minimise capital barriers.**

Targeted policies that accelerate the deployment and adoption of CERs and the aggregation of distributed resources not only transfer equity and agency in the NEM to consumers and reduce their energy bills, but provide necessary grid stability and security.

As the adoption of EVs – batteries on wheels, with the potential to send power to the grid (V2G) – and deployment of small-scale batteries accelerates, Queensland has the opportunity to leverage its world-leading solar to aggregate CERs into VPPs across homes, C&I properties, precincts and communities to create a resilient and robust decentralised web of energy assets.

CERs can shift load from peak to off-peak hours, reducing grid load during supply shortages, even as distributed batteries utilised during periods of peak renewable penetration reduce utility-scale solar curtailment. The ability to co-locate energy generation and storage with load is a unique competitive advantage of CERs that should be leveraged as a key energy transition solution.

As well as being price-competitive and deflationary, CERs are the fastest to deploy, overcoming development and construction wait times for utility-scale assets. Distributed orchestrated networks will become increasingly important to maintaining energy security and alleviating grid pressures inherent in reliance on end-of-life thermal power plants – centralised points of weakness – as QLD moves towards retiring its coal fleet by 2035.

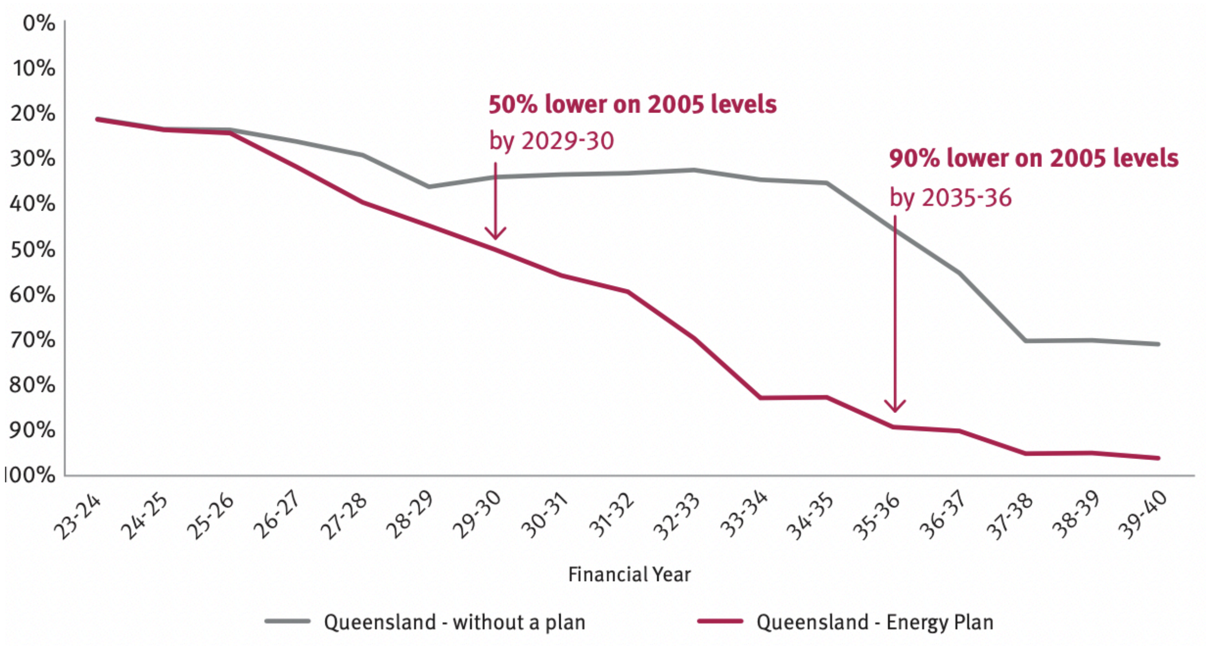
Section 1. QLD Energy and Jobs Plan

In September 2022, the QLD Government announced its QEJP and SuperGrid blueprint to turbocharge the deployment of low-cost zero emissions renewable energy generation across the state. The $62bn package aims to achieve 70% renewable energy penetration by 2032, and 80% by 2035, with 25GW of new and existing zero emission generation.[22]

The Federal Government committed to a 43% emissions reduction target by 2030, relative to 2005, and to achieve net zero by 2050. The QLD Government had set the weakest interim emissions reduction target of any state, committing to a 30% reduction by 2030. However, by 2021, QLD had achieved a 28.7% reduction from 2005 according to Australia's National Greenhouse Accounts.[23] Since 2005, QLD's emissions from energy and fuel combustion grew by 14% into 2021, accounting for over 67% of QLD's total GHG emissions.[24] Following the accelerated decarbonisation roadmap of the QEJP, QLD has now committed to a 75% reduction target by 2035, relative to 2005.[25]

The decarbonisation of QLD's fuel and energy industry is critical to realising the state's, and Australia's, emissions reduction targets. The introduction of the QEJP, accelerating renewable energy generation and fast-tracking the phase out of coal-fired generation, will facilitate the decarbonisation of households and heavy industry reliant on QLD's grid. Realising the QEJP commitment to achieving 80% renewable energy penetration by 2035, means QLD can achieve a 90% reduction in state electricity emissions by 2035-36, setting the state up to achieve its 75% emissions reduction target by 2035, and accelerate the pathway to net zero well ahead of its 2050 target - Figure 1.1.

Figure 1.1: Emissions Reduction from Realised Energy and Jobs Plan

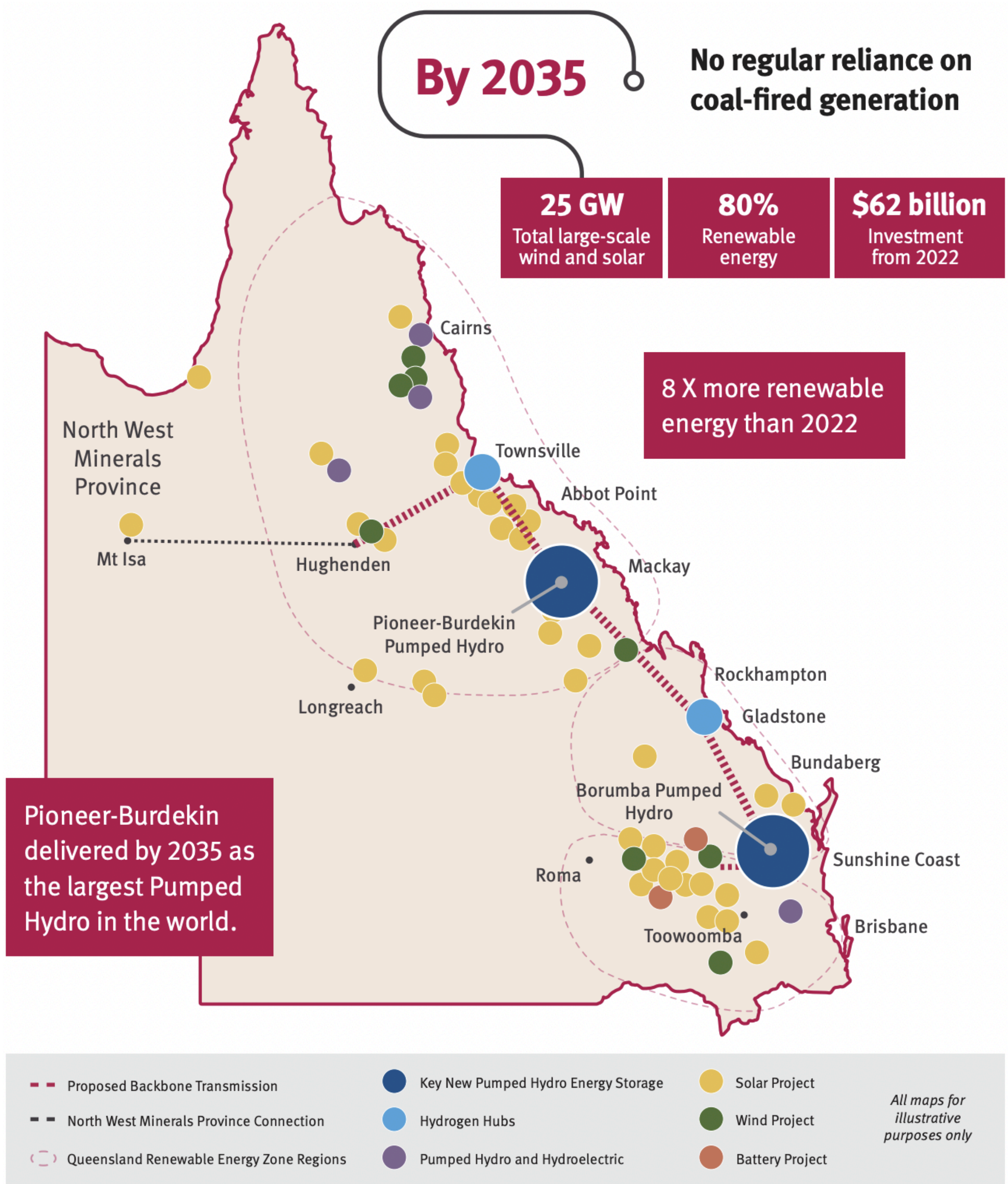


Source: QLD Energy and Jobs Plan

[22] QLD Government EPW, Queensland Energy and Jobs Plan, September 2022
[23] DCCEEW, Australia's National Greenhouse Accounts – Emissions by State and Territory, 2021
[24] DCCEEW, Australia's National Greenhouse Accounts – Emissions by State and Territory, 2021
[25] QLD Government, 75 by 2035: Queensland Powers Ahead with New Emissions Target, 15 December 2023

The deployment of 25GW of large-scale wind and solar by 2035 is supported by QLD's SuperGrid Infrastructure Blueprint - Figure 1.2. The foundational infrastructure roadmap sees investment in transmission and distribution (T&D) – wires and poles – that will connect REZs to industrial precincts and facilitate the decarbonisation of the state's largest emitters, and unlock new industries and opportunities like the $500bn of resource deposits in the NWMP. Projects safeguard QLD's economy as the world transitions to a low-carbon future, providing massive investment opportunities to pivot the state away from its excessive reliance on coking coal exports.[26]

Figure 1.2: Queensland SuperGrid Roadmap



Source: QLD Energy and Jobs Plan

[26] QLD Government EPW, Queensland SuperGrid Infrastructure Blueprint, September 2022

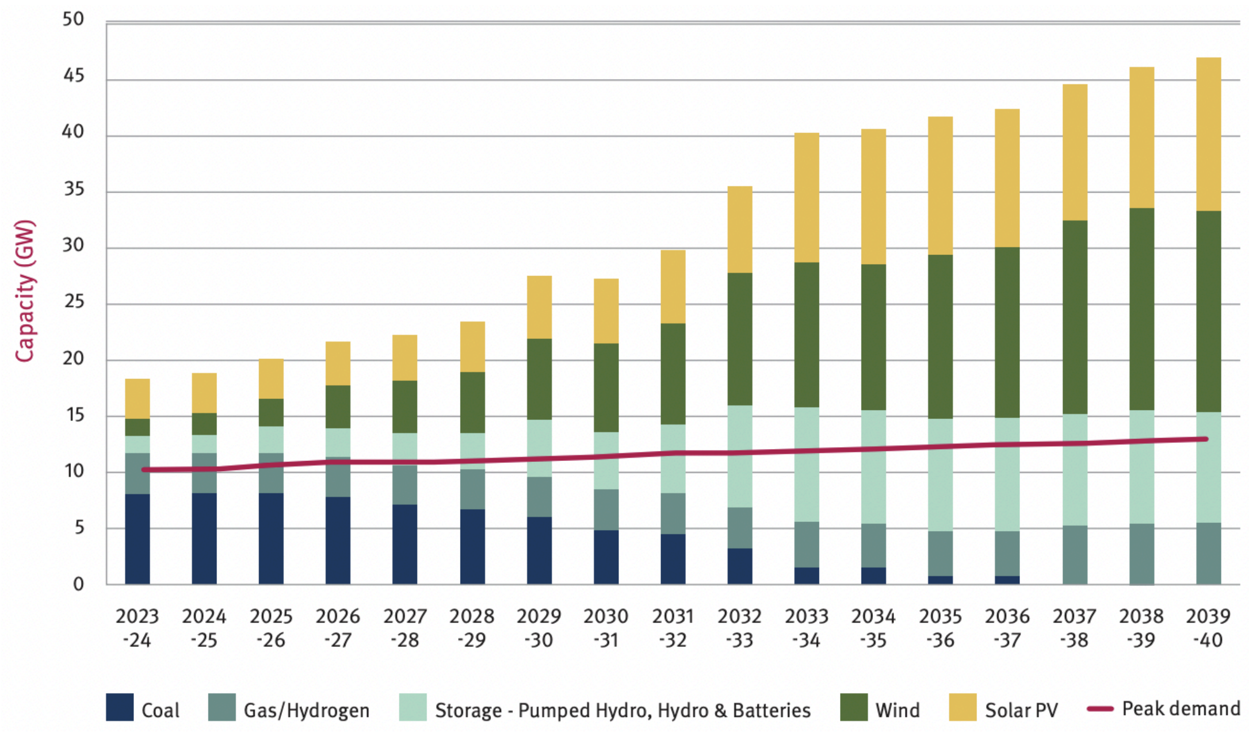
The QLD SuperGrid Infrastructure Blueprint aims to bring online 25GW of aggregated large-scale renewable energy generation, alongside 7GW of new rooftop solar PV to meet the QLD's forecasted demand in 2035 without regular reliance on coal-fired generation. As end of life coal-fired capacity retires, thermal plant sites will be repurposed to clean energy hubs, operating as synchronous condensers to provide system inertia and grid stability. The clean energy hubs are planned to be fitted with further grid-firming battery systems.[27]

The SuperGrid Blueprint highlights the need for grid-firming solutions to underpin the transition to a renewable energy grid. The QLD Government has a planned 7GW of long-duration storage, 3GW of grid-scale battery storage and a further 3GW of new methane gas capacity by 2035.

As QLD's grid becomes increasingly decentralised, upgraded and expanded network transmission and distribution will be required. Under QLD's modelling, four new high-voltage (up to 500kV) backbone transmission projects will need to be constructed by mid-2030s, connecting generators, PHS and grid-firming battery systems with load centres. This includes the CopperString 2032 project – a ~1,100km connection from Townsville to Mount Isa, connecting the NWMP and NQCEH REZ.

The significant scaling of renewable energy generation, storage and T&D is to accelerate the phase-out of coal-fired thermal generation from QLD's energy mix in order to achieve the state's ambitious renewable energy target and to expedite QLD's emissions reduction targets - Figure 1.3.

<u>Figure 1.3: Queensland Grid Capacity Transformation from Energy and Jobs Plan</u>



Source: QLD Energy and Jobs Plan [28]

[27] QLD Government EPW, Queensland SuperGrid Infrastructure Blueprint, September 2022
[28] QLD Government EPW, Queensland Energy and Jobs Plan, September 2022

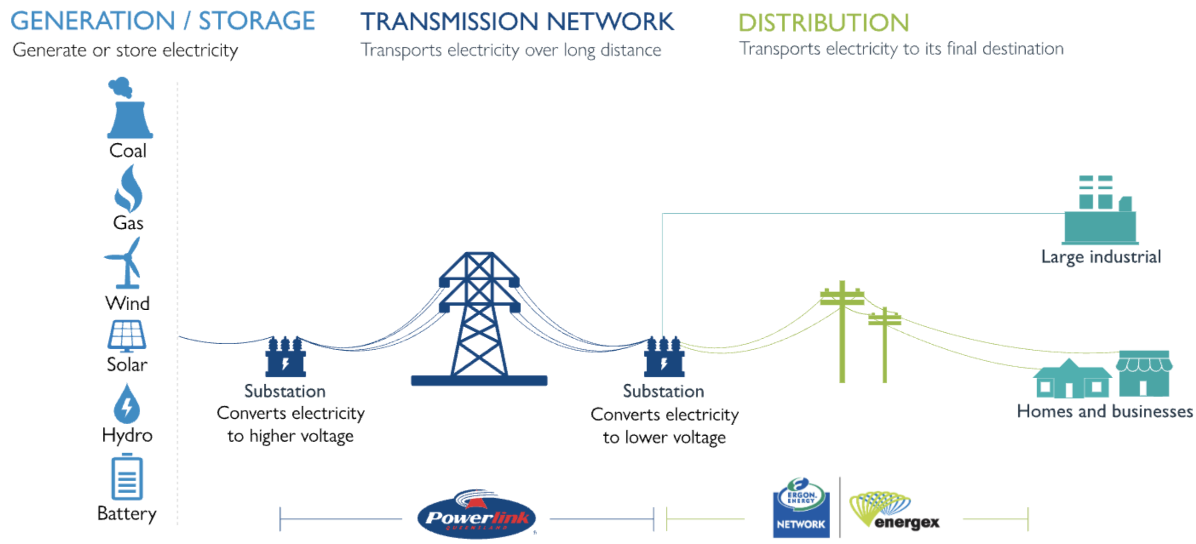
Section 1.1. Renewable Energy Zones and New Grid Connections

Queensland is a large state, covering over 1.7 million square kilometres across its mainland, 75% larger than South Australia and over 2x larger than NSW. Thus, QLD requires greater investment into electrical infrastructure T&D to supply power to its residents. This huge size and low population density combines with excellent renewable resources to give the state a huge competitive potential in zero emissions industries of the future. Queensland has a second major advantage over its southern neighbours, retaining state government ownership of grid T&D, as well as much of the state's historic generation capacity.

Powerlink is responsible for the majority of the development and operation of high-voltage electrical transmission across the state, extending 1,700km from Cairns to the NSW border, encompassing over 15,000km of circuit transmission lines and managing 147 electrical substations.[29]

Energex and **Ergon Energy** are the major operators of lower-voltage distribution networks across the state. Energex is responsible for the distribution network of 56,000km of power lines and underground cables across SEQ, while Ergon Energy's network consists of 178,000km of distribution cables across rural and regional QLD.[30] The roles of Queensland's T&D network service providers is illustrated in Figure 1.4.

<u>Figure 1.4: Queensland's Transmission and Distribution Network</u>



Source: Powerlink

As Queensland transitions to a decarbonised grid, significant new capacity from VRE generation and dispatchable clean energy storage must come online. As highlighted in Section 1.0, Queensland will need to build 25GW of solar and wind to replace the 8GW of current thermal capacity, to ensure no regular reliance on burning coal to power QLD's energy needs.

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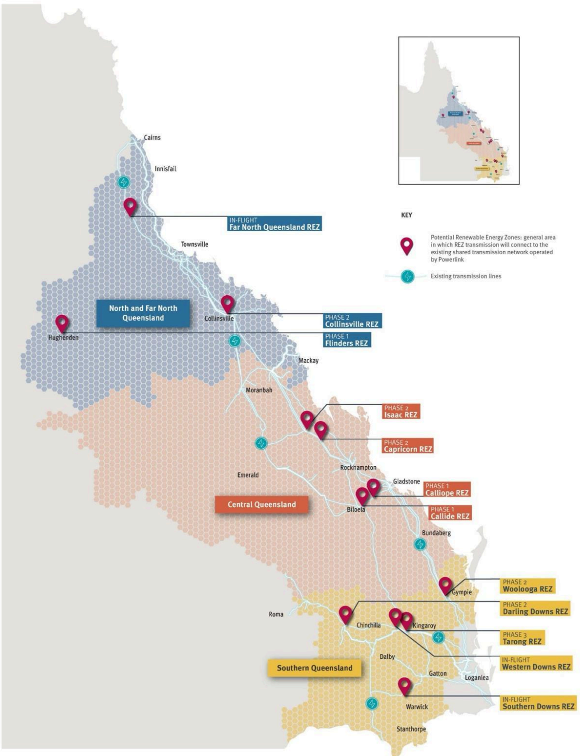
[29] Powerlink, Powerlink Infrastructure
[30] QLD Government, Electricity in Queensland, 2023

Given a Queensland regional taxpayer subsidy program of more than $500m pa,[31] T&D costs collectively are restricted so as to account for ~ 29% of Queensland's residential tariff structure in 2023-24 for T11, the main regulated residential retail tariff.[32] As part of the QEJP, the QLD Government is committed to lowering household energy bills by eliminating the exposure to fossil fuel hyperinflation through the large-scale deployment of zero-emission energy generating assets. However, given the low population density and expansive nature of the state's electricity grid, and the need for higher replacement capacity than traditional thermal generation, QLD must coordinate and orchestrate new projects and connections into regions that utilise common-user infrastructure, lowering the total capital commitment to upgrading and expanding transmission networks borne by future taxpayers whilst optimising QLD's world leading renewable energy resources.

In 2023, the QLD Government released the draft REZ Roadmap for consultation. The REZ Roadmap identified 12 potential zones with strong wind and solar resources across 3 major regions, Southern, Central and North and FNQ - Figure 1.5.[33]

Figure 1.5: Potential Renewable Energy Zones Queensland



Source: QLD Government Department of Energy and Climate

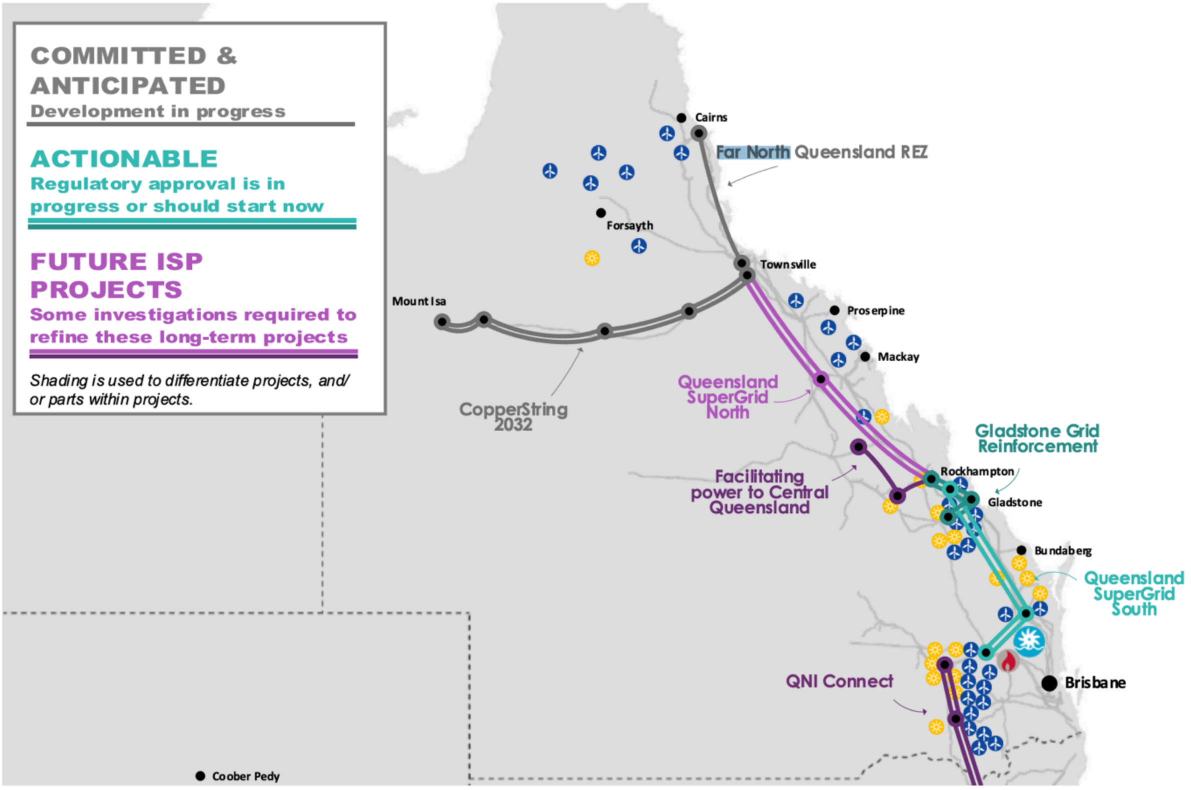
[31] The Queensland Government supports regional Queenslanders, ensuring they pay similar prices for their electricity as customers in South East Qld. This is done by subsidising additional costs involved in supplying electricity to regional Qld through payments to Ergon Energy Retail. This subsidy is called the Community Service Obligation (CSO) payment. Similar arrangements are in place for Origin Energy customers in the Goondiwindi-Texas area of the Essential Energy network. For 2023–24, the Queensland Government subsidy supporting Ergon Energy Retail customers, and Origin Goondiwindi–Texas customers, is budgeted at $541m. West Australia applies a similar scheme to protect regional electricity users. By comparison, NSW T&D costs represent ~50% of retail tariffs.

[32] Powerlink, 2023 Transmission Network Forum, 20 November 2023

[33] QLD Government, 2023 Queensland Renewable Energy Zone Roadmap, updated 12 December 2023

All 12 potential REZs were identified with the consideration for their proximity to industrial and residential energy customers, as well as the current land use, environmental and agricultural impacts and regions for future economic development. The QLD Government has begun the development of major transmission projects in the North and FNQ region to connect the state's existing and emerging industrial hubs with significant renewable potential in regional Queensland - Figure 1.6.

Figure 1.6: Draft 2024 ISP Transmission Projects in Queensland



Source: 2024 Draft ISP Appendix 5. Network Investments [34]

CopperString 2032 is the largest ever economic development project in North Queensland, and the largest expansion to the power grid in Australia. As part of the QEJP, Powerlink will construct a $5bn expansion of 500kV transmission lines over 1,100km to connect Townsville and Hughenden.[35] In October 2023, the QLD Government announced a $1.3bn package to progress CopperString planning, with the project set to begin construction in mid-2024.[36]

The project will connect the QLD SuperGrid to the NWMP, a 375,000km^2 region that contains one the world's richest deposits of critical minerals, with an estimated value of $500bn. Connecting the NWMP to the electrical grid will provide low-cost firmed renewable energy to power new mining and refining projects in Queensland, developing value-added decarbonised industries to safeguard its economy from the terminal decline of global thermal and metallurgical coal demand.

[34] AEMO, 2024 Draft ISP Appendix 5. Network Investments, 15 December 2023
[35] QLD Government, What is CopperString 20342 and Why is it Important for Queensland's Renewable Energy Future, 14 June 2023
[36] QLD Government, $1.3bn Investment to Progress CopperString 2032 to Construction, 30 October 2023

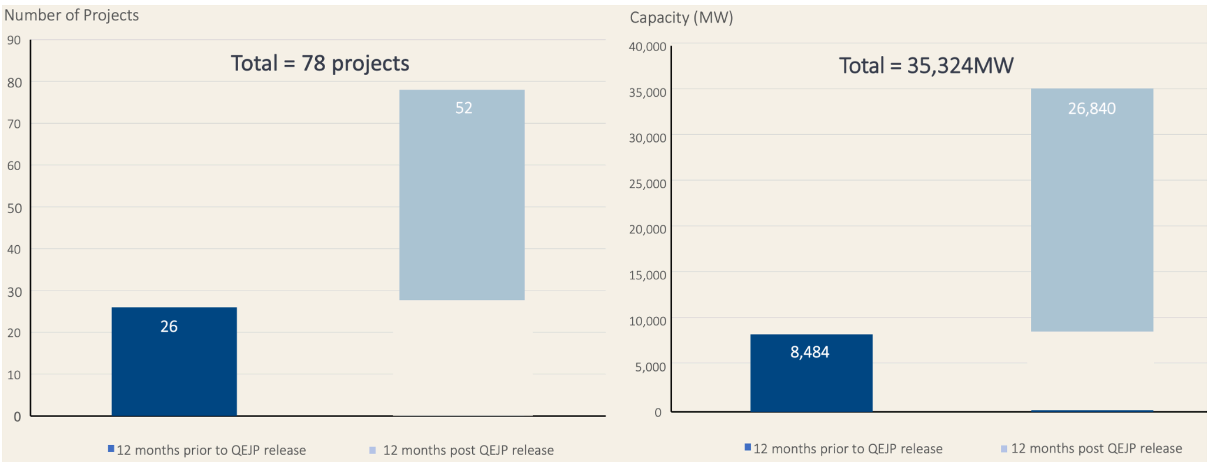
Section 1.2. Energy and Jobs Plan 2023 Update

One year since the introduction of the QEJP, renewable energy now accounts for 27% of energy demand, positioning QLD to reach its first renewable energy target of 50% by 2030.[37] Rooftop solar is the powerhouse of QLD's renewable energy generation, with 5.96GW of capacity across 1 million rooftops by the start of 2024.[38]

In 2023, rooftop solar capacity grew by 13%, supported by new large-scale generation projects to supercharge renewable energy penetration, up over 20% year-on-year (yoy). New large-scale projects include the Dulacca Renewable Energy Project (180MW), Edenvale Solar Park (146MW), Kaban Green Power Hub (157MW), Moura Solar Farm (92MW), and Wandoan South Solar Project Stage 1 (125MW).

Whilst projects that have been commissioned in 2023 were in development prior to the Plan, the QEJP has created a monumental market signal for private developers of clean energy assets. 1-year post QJEP, 26,840MW of new large-scale capacity had lodged a connection enquiry with Powerlink, over 3x that of the 12-months prior - Figure 1.7.[39] The average size of new projects also grew 58% following the QEJP, rising to 516MW/project from 326MW/project in the prior year.

Figure 1.7: Powerlink Connection Enquiries Prior and Post QEJP Release



Source: Powerlink 2023 Transmission Network Forum

In March 2023, QLD committed $1.1bn to the CopperString 2032 project to connect the NWMP to the NEM. This was followed by a $19bn budget allocation in June 2023 over four-years to support new transmission, wind, solar and storage capacity. Of the $19bn, the allocation includes $5.5bn to QLD energy entities in 2023-24, as well as an allocation of $1.5bn in further electricity bill relief for QLD households and small businesses to combat cost of living pressures in the current fiscal year.[40]

In July 2023, QLD released the draft REZ Roadmap for consultation, aimed to coordinate clean energy infrastructure development across the state. QLD committed $145m to support initial investment into 3 key regions to host a number of REZs. There are now 12 potential REZs identified across Qld.

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[37] Queensland EPW, Energy and Jobs Plan 2023 Update, November 2023
[38] CER, Postcode Data for Small-Scale Installations, 16 January 2024
[39] Powerlink, 2023 Transmission Network Forum, 20 November 2023
[40] QLD Government, $19bn to be Invested to Transform QLD into Renewable Energy Powerhouse, 13 June 2023

QLD Government is progressing to deliver:

- $500m in investments into batteries for publicly-owned energy businesses via the boosted Queensland Renewable Energy and Hydrogen Jobs Fund (QREHJF)
- The Queensland Battery Industry Strategy
- The REZ Framework legislation to accelerate the deployment of 22GW of new renewable energy capacity by 2035
- A joint venture to build, own and operate a new 200MW hydrogen-ready gas peaking power station at Kogan Creek
- 100% energy demand for all large government sites to be sourced from renewable energy by 2030
- 100% penetration of smart meter devices across the state by 2030 to increase network access and orchestrate CERs

The QLD Government also provided a $550 electricity bill relief to every Queensland household via the 2023-24 Cost of Living Rebate. The Climate Smart Energy Savers rebate program, launched in September 2023, has had overwhelming support by households. The Smart Energy Savers provides $300-1,000 in rebates for upgrading to 4-star, or higher, energy efficient appliances including refrigerators, washing machines, dryers, air conditioners and solar and heat pump hot water systems. The Scheme will support over 80,000 households.

Section 2. Queensland's Energy Demand and Forecast

Under AEMO's Central (Step Change) Scenario, QLD demand will grow from 52TWh in FY23 to 89TWh in FY36, at a CAGR of +3.3%, ahead of the +1.9% CAGR experienced since FY00. To achieve QLD's ambition of 80% renewables by 2035, renewable energy must supply 69TWh in FY35. From renewable penetration of 25% in FY23, renewables must grow at a CAGR of 13.3% through to FY36.

Since FY2000, QLD's energy grid has grown by an average CAGR of 1.9% to FY23, currently producing 60.9TWh. Energy demand growth has slowed over time, growing by 0.9% CAGR over the last 5 years. Coal continues to be the dominant fuel source for Queensland's electricity demand, accounting for 71% (43.2TWh) in FY23 - Figure 2.1.

Over the last 5-years, renewable energy generation's share has significantly ramped up, growing from 6% in FY18 to 25% in FY23.[41] Rooftop solar PV is the largest zero-emission energy source in QLD, supplying 6.9TWh in FY23. As a result, absolute coal-fired generation has fallen by 19% since FY18.

Figure 2.1: QLD Demand Growth and Share of Generation

Year	Total Demand GWh	Total RE GWh	Coal %	Fossil Gas %	RE %	VRE %
FY99	21,979	596	97%	1%	3%	0%
FY00	39,923	896	97%	1%	2%	0%
FY01	41,892	848	98%	1%	2%	0%
FY02	44,884	593	102%	1%	1%	0%
FY03	46,295	365	104%	2%	1%	0%
FY04	48,998	783	105%	2%	2%	0%
FY05	50,006	833	104%	4%	2%	0%
FY06	50,992	544	104%	7%	1%	0%
FY07	51,771	1,012	99%	10%	2%	0%
FY08	51,404	895	98%	11%	2%	0%
FY09	52,474	821	98%	11%	2%	0%
FY10	53,256	609	94%	16%	1%	0%
FY11	51,716	1,140	89%	22%	2%	0%
FY12	52,132	1,221	86%	21%	2%	1%
FY13	52,207	1,697	84%	18%	3%	2%
FY14	51,766	2,195	77%	21%	4%	3%
FY15	54,733	2,333	81%	24%	4%	3%
FY16	57,288	2,430	84%	15%	4%	3%
FY17	58,532	2,905	87%	12%	5%	4%
FY18	58,202	3,235	92%	10%	6%	4%
FY19	59,370	6,220	87%	8%	10%	9%
FY20	59,540	8,827	81%	10%	15%	14%
FY21	59,368	10,536	78%	9%	18%	16%
FY22	60,716	12,214	73%	8%	20%	18%
FY23	60,920	15,374	71%	7%	25%	23%

Source: OpenNEM, CEF Calculations

[41] OpenNEM, Queensland Energy Consumption

As of 1HFY24, coal-fired generation has continued to fall, accounting for 67% of QLD's energy demand. In comparison, renewables have risen to supply 30% of demand, with solar rising to 23%, and distributed rooftop solar PV remaining the largest VRE generator at 13% within this.

To realise QLD's ambitious targets of 50% of electricity demand sourced from renewable energy by 2030, 70% by 2032, and 80% by 2035, zero-emissions generation must significantly scale to not only increase its penetration, and facilitate the expected expansion of demand with economic growth and decarbonisation, including electric vehicles (EV) and emerging export opportunities. The AEMO publishes an annual *Electricity Statement of Opportunities* (ESOO), a technical and market data forecast of the NEM demand.[42]

Figure 2.2: QLD Energy Demand Forecast under AEMO ESOO 2023 Central Scenario

Year	Total GWh	Total RE GWh	RE %
FY13	52,207	1,697	3%
FY14	51,766	2,195	4%
FY15	54,733	2,333	4%
FY16	57,288	2,430	4%
FY17	58,532	2,905	5%
FY18	58,202	3,235	6%
FY19	59,370	6,220	10%
FY20	59,540	8,827	15%
FY21	59,368	10,536	18%
FY22	60,716	12,214	20%
FY23	60,920	15,374	25%
FY24	58,650	17,417	30%
FY25	60,338	19,731	33%
FY26	61,677	22,352	36%
FY27	63,045	25,322	40%
FY28	64,033	28,687	45%
FY29	65,967	32,498	49%
FY30	69,328	36,816	53%
FY31	72,283	41,707	58%
FY32	75,349	47,248	63%
FY33	79,007	53,525	68%
FY34	81,921	60,637	74%
FY35	85,866	68,693	80%
FY36	89,035	77,819	87%

Source: OpenNEM, AEMO, CEF Calculations

[42] AEMO, 2023 Electricity Statement of Opportunities, 31 August 2023

Under the ESOO's 2023 Central Scenario, operational send-out (large-scale energy generation) is expected to increase to 74.4TWh in FY36 - Figure 2.2. Rooftop PV generation is forecast to double from 6.9TWh in FY24 to 16TWh in FY36. Coupled with additional small non-scheduled generation and energy efficiency gains, total electricity demand is forecast to reach 89TWh in FY36. Under the Central Scenario, total QLD demand will grow by 3.3% CAGR from FY23 to FY36.[43]

In order to meet QLD's 80% target by 2035, renewables must generate 68.7TWh under AEMO ESOO 2023 Central Scenario. This requires zero-emissions generation to grow at 13.3% CAGR.

The 2023 ESOO is currently the most up to date, full energy demand forecast published by AEMO. Whilst the Draft ISP 2024 has been released, the 2023 IASR Assumptions Workbook (Version 5.2), is the latest major update to demand growth estimates. The Draft ISP 2024 does however, provide an update for the growth of distributed rooftop PV, as well as other CERs, including BESS and virtual power plant (VPP) aggregation.[44]

The Draft ISP 2024 forecasts rooftop PV capacity to reach 13.5GW in QLD by FY36 under the Step Change scenario, generating 17.24TWh of electricity. This represents a 7.4% upwards revision in rooftop solar generation by FY36 compared to the 2023 ESOO forecast.

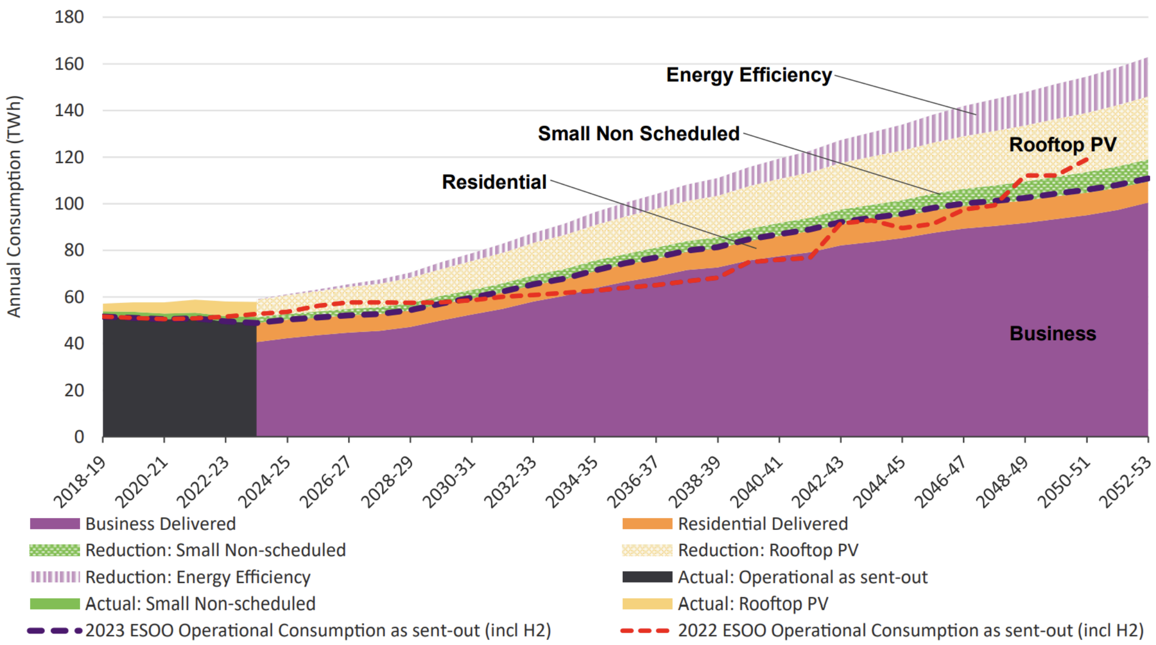
[43] AEMO, 2023 QLD ESOO Central Forecast Annual Consumption, 31 August 2023
[44] AEMO, Draft 2024 ISP, 15 December 2023

Section 2.1. AEMO Forecast Inputs and Assumptions

Under AEMO's 2023 ESOO Central Scenario, uptake of EV and the electrification of households are the primary drivers of residential electricity demand growth - Figure 2.3. Under ESOO's Inputs, Assumptions and Scenarios' (IASR) Step Change scenario, the number of EVs in QLD will grow from 22,467 in FY23, to 2.08 million by FY36. This is expected to increase energy demand from 46GWh in FY23, to 7,232GWh in FY36.[45]

Btm rooftop PV is expected to power the majority of residential demand and EV charging. AEMO forecasts rooftop PV capacity in QLD to double from 6GW in FY24 to 12.6GW, producing 16TWh, in FY36. The accelerated uptake of energy-efficient appliances, coupled with the expedited deployment and orchestration of CERs – i.e. btm battery storage, solar and heat pump hot water systems – into VPPs can significantly reduce the operational send-out to households. The critical benefits DERs and VPPs will play in QLD reaching its renewable energy targets is discussed in Section 3.

<u>Figure 2.3: QLD Electricity Demand Forecast in 2023 ESOO Central Scenario</u>



Source: AEMO ESOO 2023 [46]

The electrification of commercial and industrial (C&I) operations – primarily transportation, chemical (ammonia) and industrial heat (alumina refining), will again be a primary driver for increased load. The emergence and growth of green hydrogen industries for Queensland has the potential to be a significant additional driver of industrial electricity demand.

[45] AEMO, 2023 IASR Assumptions Workbook, 8 September 2023
[46] AEMO, 2023 Electricity Statement of Opportunities, 31 August 2023

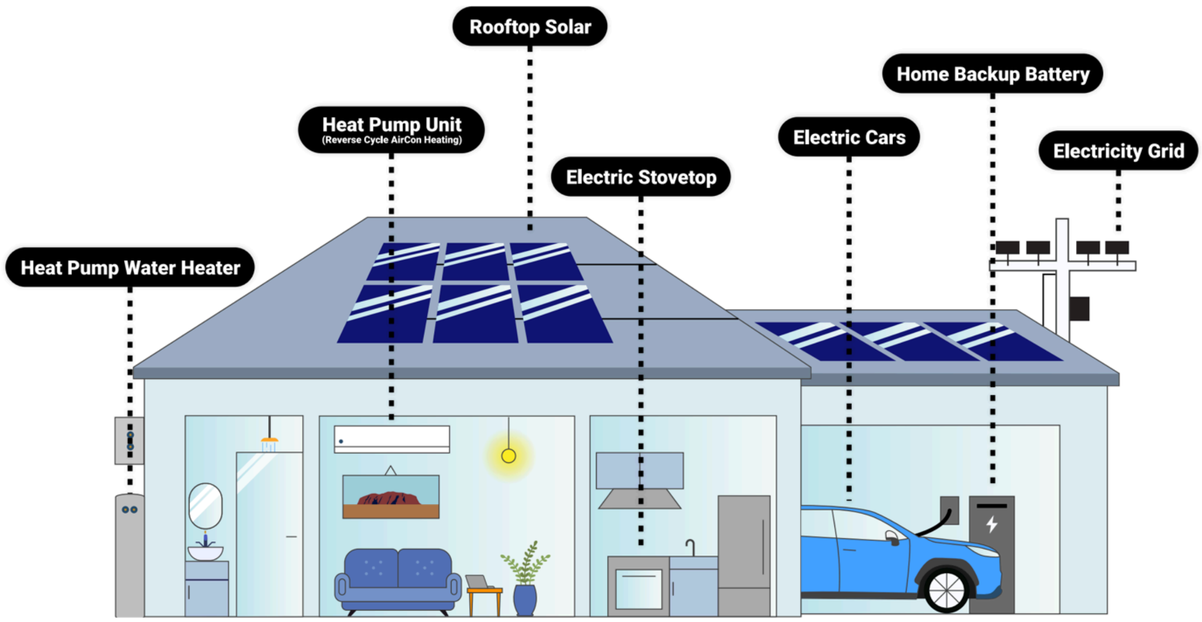
Section 3. Consumer Energy Resources and Virtual Power Plants

QLD is leading Australia and the world in rooftop solar PV, with nearly 6GW of capacity across 1 million rooftops in 2023. As solar's penetration continues to boom, effective timing of residential demand, soaking up of zero-cost solar generation into home batteries and demand shifting are critical to reducing peak demand and solving problems of minimum demand as the solar duck curve inevitably deepens. The aggregation of CERs into VPPs provides an incredible opportunity to harness Australia's dynamic energy pricing model, delivering permanent energy savings to households as time-of-use pricing structures incentivise load shifting and residential battery adoption.

The home of the future needs to be drastically different to that of the home of the past. As btm generation and storage deployment accelerates rapidly across Queensland and Australia, and 7+ star NatHER rated houses become the norm, households are gaining agency in their energy use, and equity into the NEM.

Uptake of CER is increasing among Queenslanders – small-scale, demand-side energy resources, i.e. on the side of the consumer. CERs include generating assets such as rooftop solar PV; energy storage systems like home battery storage and EVs; electrified heating such as heat pump water heaters; reverse cycle air-conditioners; and electric stovetops - Figure 3.1.

Figure 3.1: An Electrified Household in Australia



Source: Rewiring Australia [47]

The effective aggregation and orchestration of CERs within a home, and across multiple residencies, commercial and industrial properties and communities, is a vital component to time shifting demand (or load shifting) – aligning energy use with VRE generation to reduce peak demand and curtailment. At scale, with optimisation through automation and

[47] Rewiring Australia, Electrification is Anti-Inflationary

behavioural responses to financial incentives, CERs are just as important as scaling large-scale renewable generation to the goal of reaching 100% renewables.

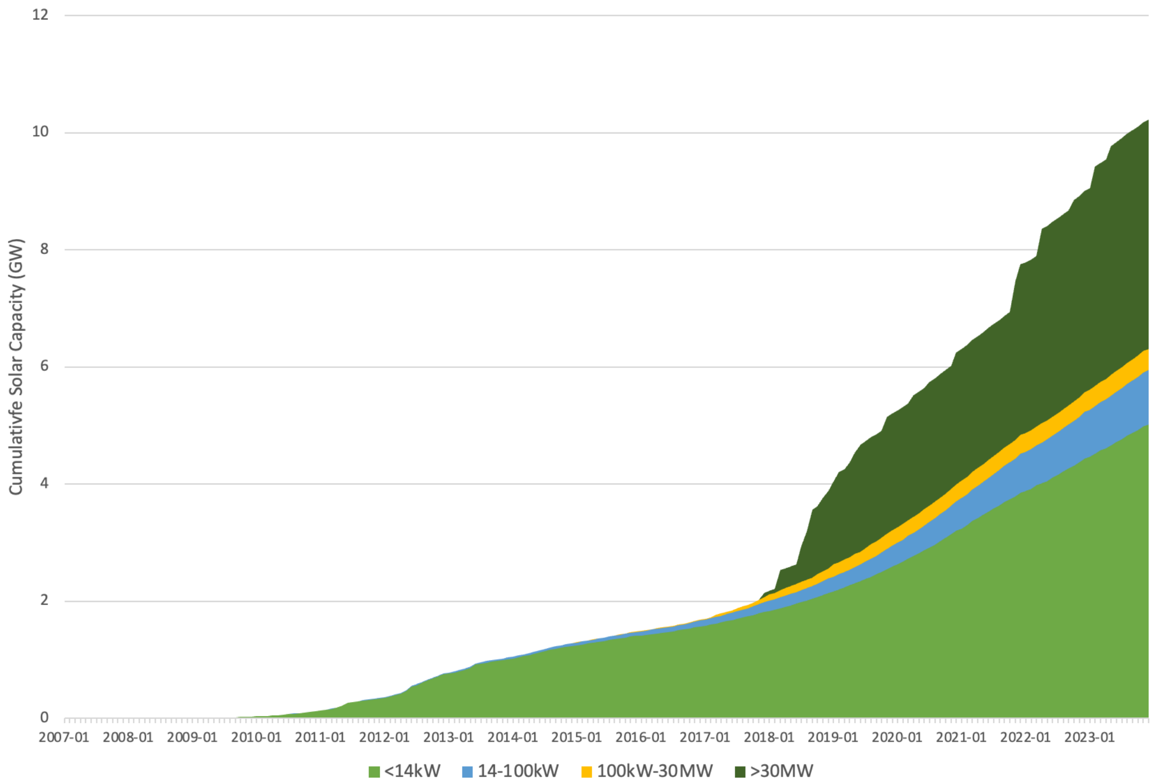
In 2023, one-third of detached homes in the NEM have rooftop solar. By 2050, ~79% of detached homes are forecast to be equipped with solar, quadrupling distributed solar capacity to 86GW.[48]

The growth in new rooftop solar systems has averaged 12% year-on-year over the past 5 years, reaching 1 million systems across Queensland and 3.1 million systems across the NEM in 2023.[49] Coordinating the growth of rooftop solar with associating btm storage presents a significant opportunity for Queensland to leverage to meet its renewable energy targets.

Section 3.1. Rooftop Solar PV

Distributed rooftop solar PV is the second largest contributor to QLD demand, and the largest source from renewable energy. In 2023, rooftop solar in Queensland generated 7.62TWh of electricity, supplying 12.2% of demand.[50] Rooftop solar continued to be the lowest cost source of electricity, averaging $25.82/MWh throughout 2023, a quarter of the average wholesale price of black coal.

Figure 3.2: Queensland Rooftop + Utility-Scale Solar PV Cumulative Capacity



Source: Australian PV Institute [51]

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[48] AEMO, Draft 2024 ISP, 15 December 2023
[49] AEMO, Draft 2024 ISP, 15 December 2023
[50] OpenNEM, Energy Queensland 2023
[51] APVI, PV Postcode Data, September 2023

Rooftop solar is the powerhouse of QLD's renewable energy generation, with 5.96GW of capacity across 1 million rooftops at the start of 2024 - FIgure 3.2.[52] In 2023, Queensland added 1.2GW of solar capacity, with 587MW from rooftop solar PV arrays below 14kW.

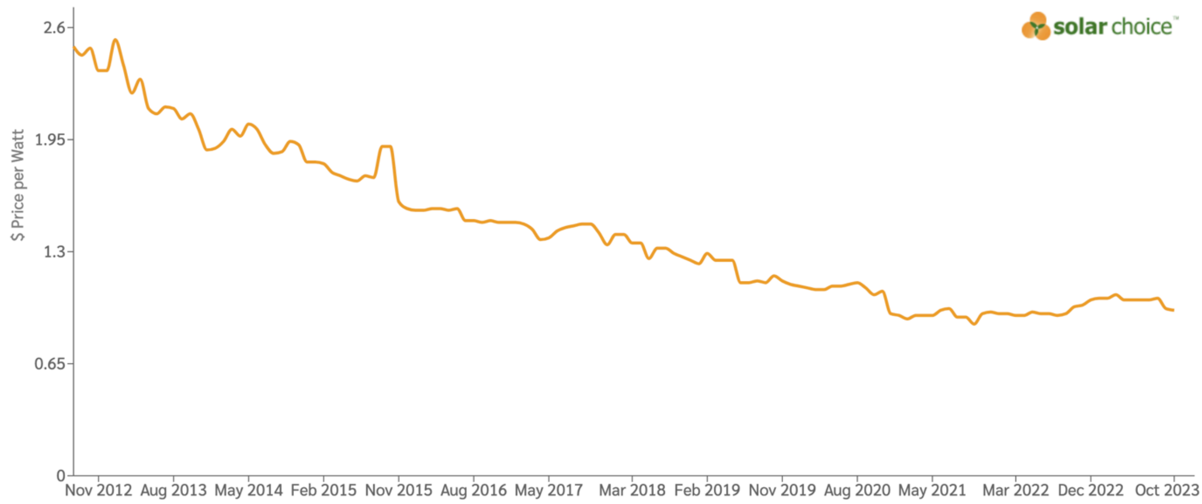
Queensland is the global leader for solar capacity per capita. In April 2023, the IEA's Snapshot of Global PV Markets identified Australia as the leading solar country per capita, reaching 1,166W/capita, ahead of the Netherlands and Germany.[53] Fast forward to 2024, Australia now has an average solar penetration of 1,285W/capita, with Queensland at a staggering 1,872W/capita, the solar capital of the world.[54]

Residential systems have driven the steady rise in solar penetration. Residential arrays under 14kW account for 50% of Queensland's solar capacity, totalling 5GW as of December 2023.[55] According to the Australian PV Institute, Queensland has the highest share of houses equipped with a PV system, at 45.4%.[56]

The rapid rise in rooftop solar is owed to the deflationary nature of solar. As solar penetration continues to rise, given the variable nature of generation and the dynamic pricing model of the NEM, generators not locked into long-term PPAs will compete to supply low-cost solar to the wholesale market, lowering the cost to consumers. In addition, as more module manufacturing capacity comes online, the cost of systems will continue to decline.

Solar Choice illustrates the deflationary nature of installing solar in Queensland. In October 2023, the cost of solar reached $0.96/W, a 54% decline from a decade prior - Figure 3.3.

Figure 3.3: QLD Solar Choice Price Index to October 2023



Source: Solar Choice [57]

It is valuable to note the scale cost advantages for residential solar PV across Australia and Queensland. Total retail price to customer, including up-front incentives for small-scale systems, is $1.33/W for a 3kW array, compared to $0.96/W for a 10kW array, representing a

[52] CER, Postcode Data for Small-Scale Installations, 16 January 2024
[53] IEA-PVPS, Snapshot of Global PV Markets 2023, April 2023
[54] Figures based on APVI Postcode Data as of 31 December 2023, and ABS Population statistics as of 31 June 2023
[55] APVI, PV Postcode Data, September 2023
[56] APVI, Mapping Australian Photovoltaic Installations, accessed December 2023
[57] Solar Choice, Solar Panel Costs: Solar Choice Price Index, 1 November 2023

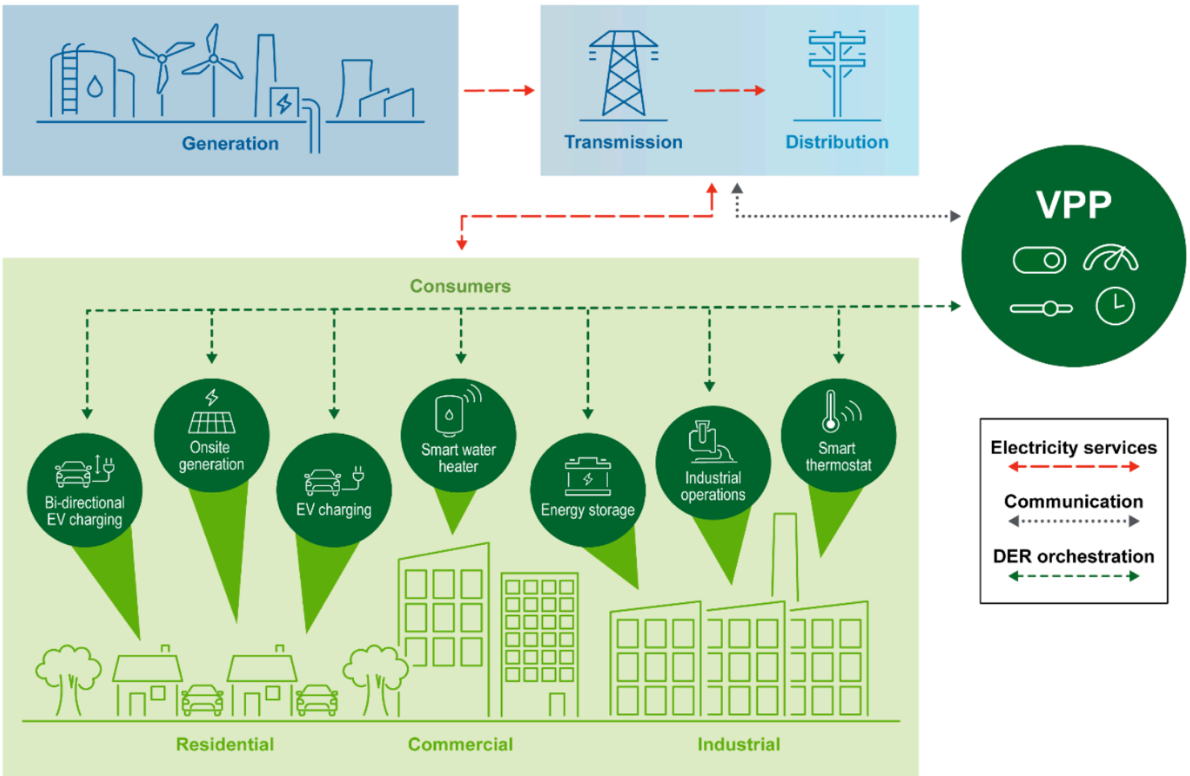
29% price advantage for a larger system.[58] As household electrification continues to expand, and households are provided financial incentives for energy trading and load shifting, the Queensland community will be rewarded with further cost advantages as old small systems are replaced with more efficient modules, and dramatically larger arrays.

Section 3.2. Virtual Power Plants

Given the abundance of distributed rooftop solar PV in Queensland, the state must recognise the importance of orchestrated btm generation and storage to reduce the demand on large-scale generation and the pressure on transmission and distribution networks. Queensland can capitalise, by leveraging **VPPs**.

VPPs are aggregations of CERs, including rooftop solar, btm battery systems, EVs and associated charging infrastructure, electric water heaters, smart buildings, and flexible C&I loads that balance electrical supply and demand, providing utility-scale grid services like traditional power plants - Figure 3.4.[59]

Figure 3.4: Visual Representation of VPPs



Source: US Department of Energy [60]

CERs provide electricity demand flexibility, electricity generation, storage and services at small scale (sub-utility), typically connected to lower-voltage grid distribution networks. CERs can be used to strategically shift demand from peak to off-peak hours, reducing grid load during supply shortages i.e. load-shifting. VPPs can operate by shifting the timing of EV

[58] Solar Choice, Solar Panel Costs: Solar Choice Price Index, 1 November 2023
[59] US DoE, Pathways to Commercial Lift-off: Virtual Power Plants, 12 September 2023
[60] US DoE, Pathways to Commercial Lift-off: Virtual Power Plants, 12 September 2023

charging to avoid overloading local distribution system equipment, supplying homes with energy from on-site solar + storage systems during peak hours to reduce demand on the bulk power system, charging distributed batteries during periods of peak penetration to reduce utility-scale solar curtailment, dispatch energy from EVs via vehicle-to-grid (V2G) technology, and contribute to ancillary services to maintain grid stability.

By changing consumer behaviour and reshaping demand curves and providing additional grid services from CERs, VPPs have the potential to increase the resources and flexibility of Australia's grid at a lower cost than centralised assets.

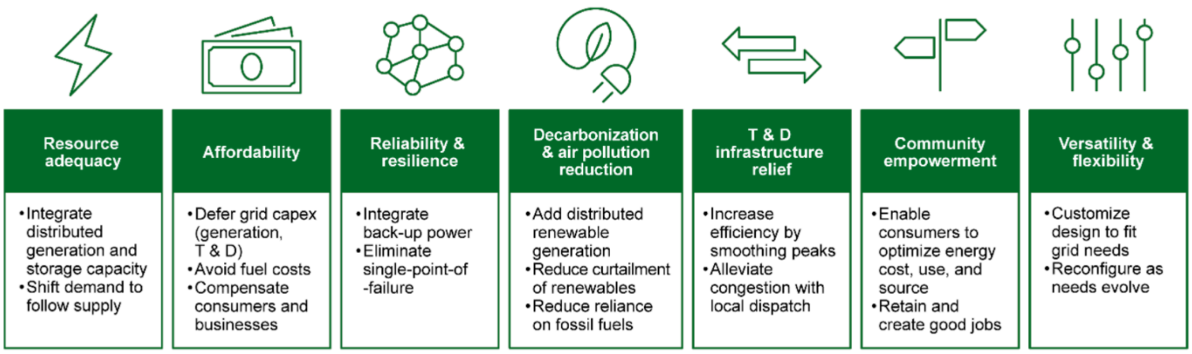
VPPs are a critical component to overcoming T&D congestion challenges during high-load conditions, increasing overall grid efficiency by reducing and shifting peak demand. Smoothed power flow from VPPs can contribute to higher average utilisation of T&D infrastructure. Reducing the demand for gas peaking plants, as well as reducing curtailment of utility-scale clean energy generation using btm storage, will result in higher investment yields in clean energy assets, crowding in further capital for new projects.

The US Department of Energy (DoE) has prioritised CER adoption and VPP aggregation to provide genuine electricity bill savings, improve grid reliability and resilience, as well as reduce the emissions of energy consumption. Enabling VPP rollout through low-cost financing and rebates for energy-efficient, VPP-enabled devices, and exposing consumers to wholesale market pricing will create a structural change in which we use electricity, with financial incentives to induce load-shifting behaviour and further reduce energy bills.[61]

Financial Incentives

VPPs aggregate residential, commercial and industrial electricity consumers into models that offer rewards for contributing to efficient grid operations - Figure 3.5. By incentivising demand shifting to follow supply, VPPs will result in lower grid capex, enhance grid liability through decentralisation and reduce curtailment of low-cost zero emissions generation.

<u>Figure 3.5: Value Proposition of Virtual Power Plants</u>



Source: US Department of Energy [62]

The energy produced by Queensland rooftops is already the largest renewable energy generator in the state. For the state to leverage the existing, and quickly-growing capacity of btm generation, the QLD Government must incentivise the adoption and deployment of btm storage and the electrification of household energy demand (i.e. conversion from methane gas heating to electricity and the transition from fossil-fuel transport to EVs).

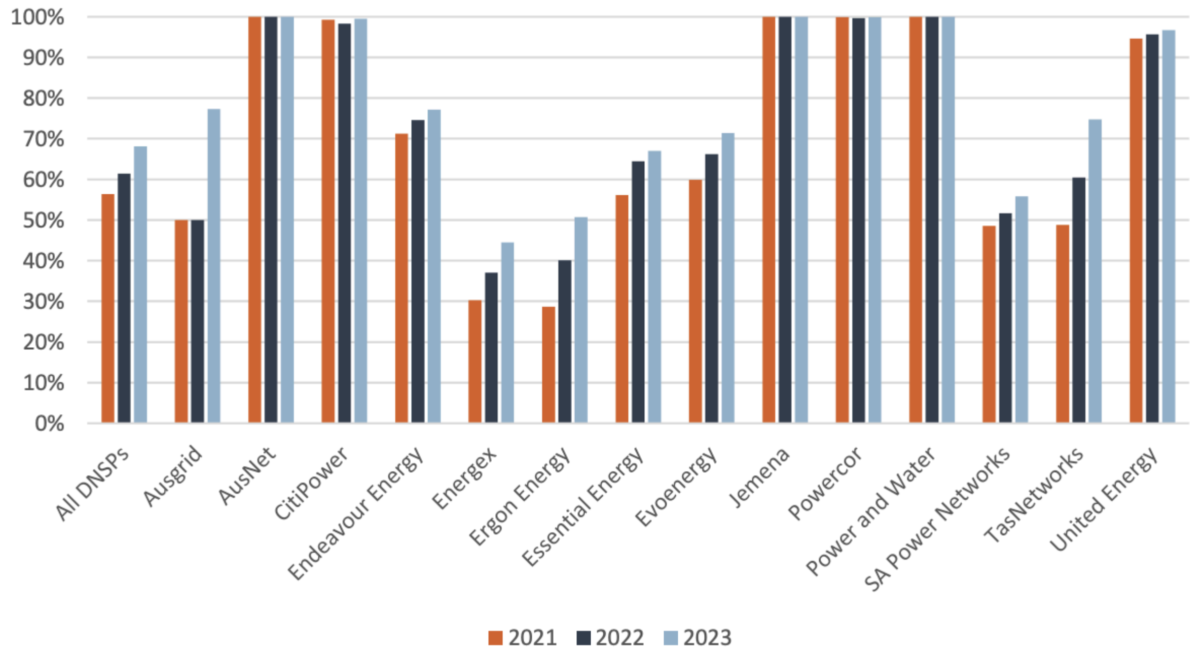
[61] US DoE, Pathways to Commercial Lift-off: Virtual Power Plants, 12 September 2023
[62] US DoE, Pathways to Commercial Lift-off: Virtual Power Plants, 12 September 2023

Queensland's Energex and Ergon Energy had the largest and 3rd largest proportion of their customers using export services (i.e. energy from solar and batteries supplying the energy grid) in 2023, of all Distributed Network Service Providers (DNSPs) across Australia, with SA Power Networks the 2nd highest proportion. 43% of Energex customers utilised export services in 2023, and 32% of Ergon Energy customers.[63] However, only ~2% of export service customers from both Ergon Energy and Energex had batteries installed, with the vast majority coming from excess solar generation.

Whilst CEF recognises all rooftop solar PV systems installed since 2010 must have an associated smart meter, Queensland DNSPs with consumer export services have the lowest proportion of smart meters across Australia. Despite 43% of Energex and 32% of Ergon Energy customers utilising export services, only ~ 45% and 50% of those respective customers have smart meters - Figure 3.6. This is the lowest penetration of smart meters across all DNSPs in Australia.

As the solar duck curve becomes more pronounced with the rapidly increasing deployment of utility-scale and distributed solar PV, smart meters are a critical component of the grid transformation to transfer energy bill relief to consumers. As the duck curve deepens, wholesale market prices are increasingly dropping below zero during periods of peak solar generation. Energy consumers need to be educated about, and exposed to, the benefits of negative energy pricing through accessing time-of-day dynamic pricing. Greater adoption of smart meters and access to variable prices are key to accelerating the adoption of CER storage.

<u>Figure 3.6: Proportion of Export Service Customers with Smart Meters</u>



Source: Australian Energy Regulator [64]

The QLD Government is moving in the right direction. Under the QEJP, the state government is accelerating the deployment and integration of CERs into the network with an updated

[63] AER, 2023 Export Services Network Performance Report, 20 December 2023
[64] AER, 2023 Export Services Network Performance Report, 20 December 2023

target of **100% smart meters by 2030**, as well as increasing the orchestration of CERs into VPPs (dynamic connection agreements under QEJP terminology). [65]

The majority of households in Australia are connected to the grid via fixed-rate tariffs, either as a single rate, or an off-peak and higher peak demand tariff. As Australians are charged the same for energy consumed in the middle of the night as for energy consumed during mid- to late-morning, we need a clear financial incentive to create the behavioural change to regularly shift demand to periods of high renewable penetration.

For Australia, and Queensland, to accelerate the adoption of demand-shifting behaviour and export services from btm generation and storage, smart meters to allow significant tariff reform is needed to drive widespread behavioural change. Exposing consumers to time-of-use energy prices, in which increasing solar generation is driving prices to or below zero during the day, provides significant financial incentive to store energy both generated from rooftops, and imported from the grid. Providing the required price signal to adopt CERs will also reduce the curtailment of utility-scale VRE, increasing investment yields and crowding in further capital to expand capacity.

Octopus Energy

Octopus Energy is now the second largest energy retailer in the UK. **Origin Energy** purchased an initial 20% equity stake in Octopus Energy in May 2020, and had increased its investment to more than $700m. In December 2023, Origin Energy invested a further $530m, bringing its total stake 23%.[66] Alongside Origin Energy, the Canada Pension Plan Investment Board (CPP Investments) has injected a further £300m to raise its position from 6% to 11%. British-Californian firm Generation Investment Management also holds a 10% stake, alongside Tokyo Gas which holds a 10% position.

Octopus Energy operates the **Kraken** platform, an energy management platform that orchestrates CERs and analyses real-time wholesale electricity prices and large-scale generation to time btm generation and storage, as well as the import and export of energy into the grid to maximise energy savings for customers. Kraken is the world's leading example of the software opportunities that have emerged with the disruption of traditional energy systems.

Octopus Energy has partnered with **Origin Energy**, Australia's biggest utility, to deliver the energy platform to Australia. Kraken integrates smart meters, rooftop solar PV, EV charging and V2G discharging, installed btm storage, and utility-scale renewable generation to charge and power household demand during periods of low time-of-use wholesale pricing, and exporting excess energy during peak demand. In the absence of a market-wide overhaul of tariff structure in Australia, Origin Energy in partnership with Octopus Energy are using AI to bring the much-needed dynamic pricing signal to Australians, further incentivising the deployment of CERs.

Octopus Australia is integrating large-scale renewable projects to its portfolio, with the ability to integrate utility-scale generation with VPPs managed by Kraken. In October 2023, Octopus acquired the rights to the proposed 1GWh Blackstone battery project in

[65] QLD Government EPW, Queensland Energy and Jobs Plan, September 2022

[66] AFR, Origin Drops Another $530m on UK Energy Player Octopus, 19 December 2023

Queensland.[67] Octopus Australia has also acquired the 220MWh Ardandra Solar and BESS project, as well as the 180MW Dulacca Wind Farm.

Amber Electric

Amber is a wholesale electricity provider in Australia that has led the delivery of the dynamic pricing signal to Australia. Whilst Amber does not provide the level of automation, sophistication or aggregation of household demand to form VPPs, Amber provides its customers with live prices so Australians are able to see genuine savings and the impact of load-shifting to periods of high renewable penetration.

RedEarth Energy

RedEarth is a Queensland based battery energy stationary storage manufacturer, producing btm storage solutions for both on-grid and off-grid applications. RedEarth has also developed its Private Power Plant app, providing real time wholesale market pricing to consumers to optimise battery charging from both btm generation and imports from the grid during periods of negative pricing, and timing export services to maximise energy savings.

[67] Octopus Investments, Octopus Australia Acquires One of Australia's Largest Battery Projects, 4 October 2023

Section 3.3. Behind-the-meter Battery Storage

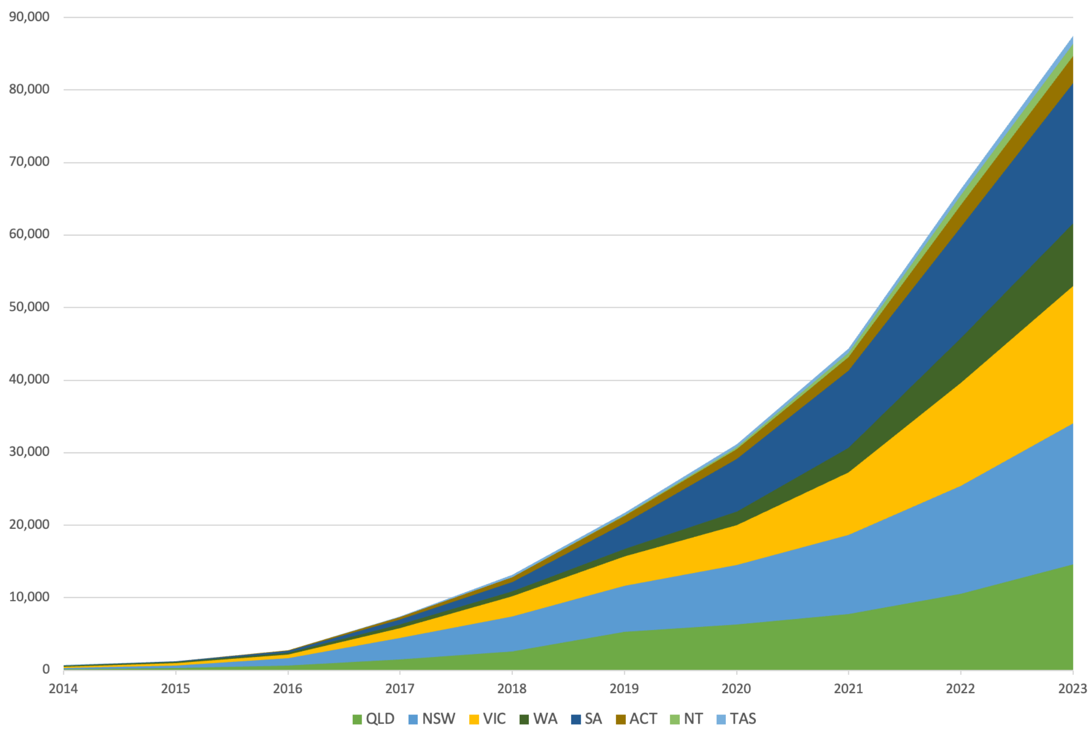
Queensland's rooftop solar PV capacity from small-scale residential systems has maintained steady growth over the past decade. As btm generation continues to expand, more households are being exposed to the deflationary nature of energy from solar, and are leveraging falling battery prices to maximise energy savings by soaking up zero-cost self-generated solar to power peak and off-peak demand. As illustrated in Section 7, average volume-weighted battery prices have fallen 90% over the past decade.

The QLD Government is expanding its support for CER storage, launching the Battery Booster program in February 2024.[68] An initiative under the QEJP, the program will provide up to a $4,000 rebate to households for the purchase and installation of btm storage systems with new or existing rooftop PV systems. Households must have a minimum installed capacity of 5kW solar PV to apply, with the battery systems a minimum of 6kWh. Households with income under $180,000 will be eligible for a $3,000 rebate, with households under $66,667 eligible for a $4,000 rebate.

There are currently 4,702 battery models registered in the approved battery list, from 46 manufacturers, including Brisbane-based RedEarth, as well global leaders including BYD, Alpha-ESS, GoodWe and LG Energy Solutions.

In 2023, 4,050 Queensland households with rooftop PV systems installed an associated battery system - FIgure 3.7. Cumulatively, there are over 14,600 residential battery systems across the state. QLD accounts for 17% of all small-scale systems with concurrent battery storage in Australia.[69]

Figure 3.7: Cumulative Number of Solar PV Systems with Concurrent Battery Storage

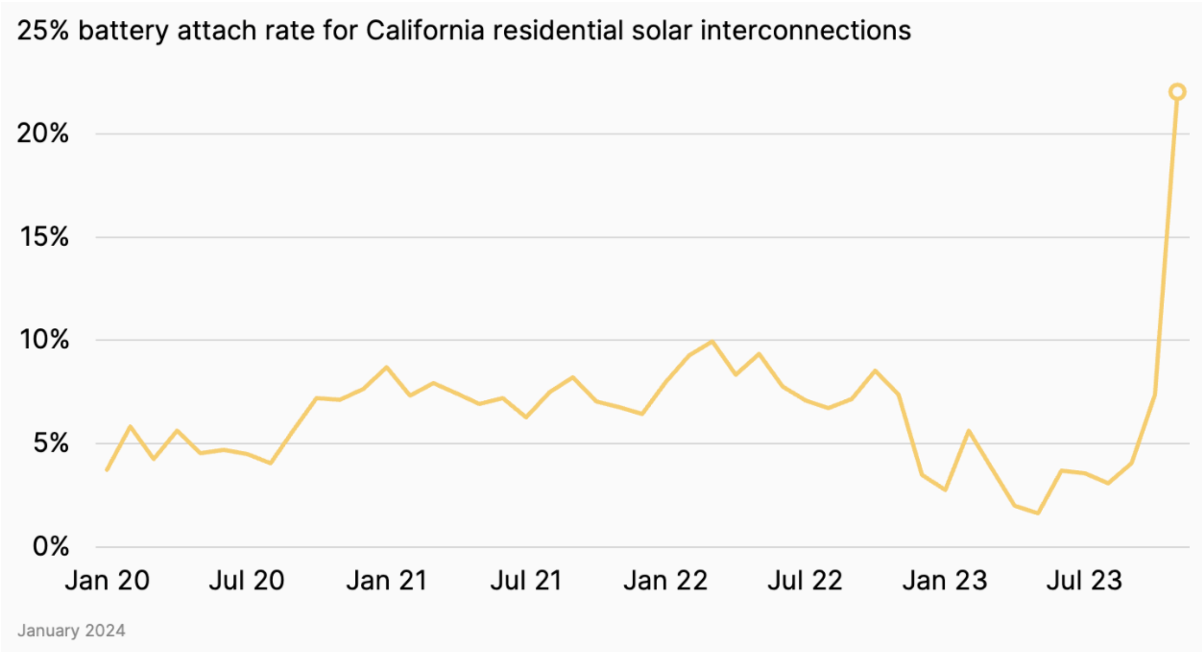


Source: Clean Energy Regulator

[68] QLD Government, Battery Booster Rebate for Householders, 12 February 2024
[69] CER, State data for Battery Installations with Small-Scale Systems, 30 November 2023

In January 2024, the QLD Government announced a $179m investment from the QREHJF, for the development of local network connected batteries across QLD.[70] The funding package will build 12 new 4MW/8MWh community batteries, adding a total of 48MW/96MWh of battery storage into regions of high distributed solar generation. These small-scale community batteries will absorb excess local energy, and discharge low-cost renewable energy to Australia's leading energy transition postcodes, building out CER deployments ahead of long timeframe grid transmission expansions and in doing so, lowering energy bills for Queenslanders as the dependence on expensive gas peakers are reduced. CEF expects rooftop solar with btm storage to surprise all forecasts with its speed of uptake, as foreshadowed in California in recent months - Figure 3.8.

Figure 3.8: California Behind-the-Meter Battery Storage Share of Solar Installs



Source: Nat Bullard

[70] QLD Government, [Battery Bonanza to Charge QLD's Renewables Future](), 17 January 2024

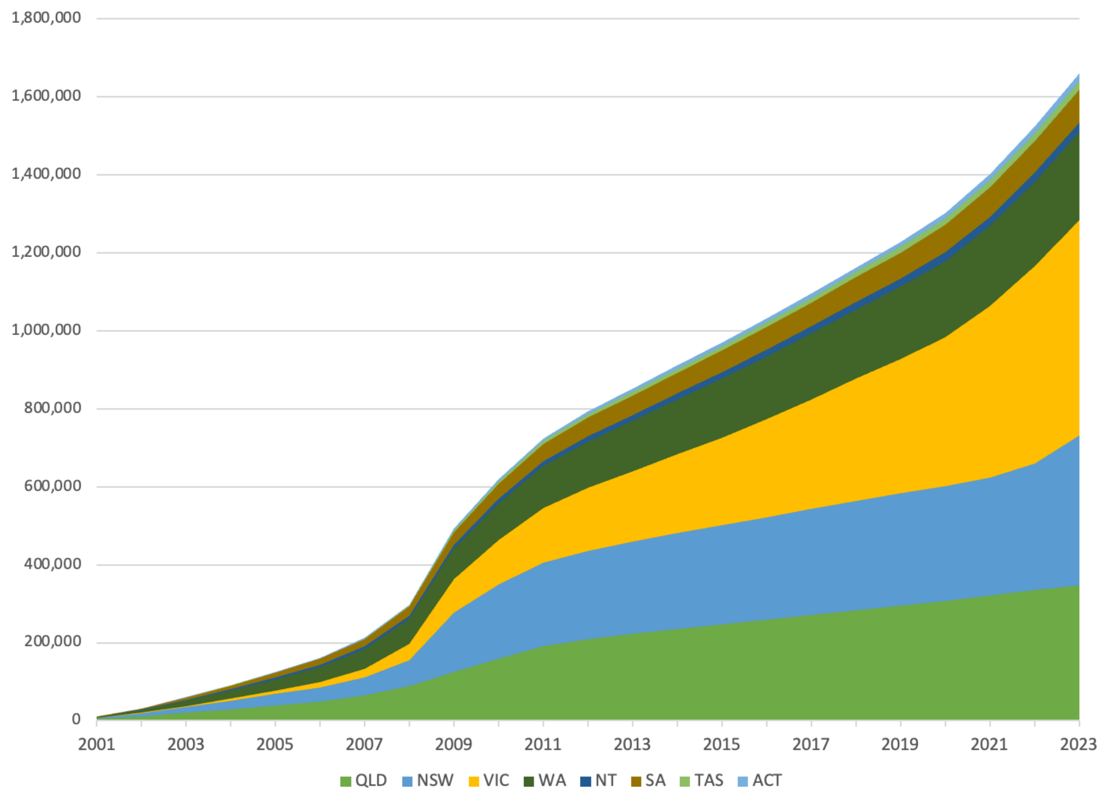
Section 3.4. Solar Water Heaters and Air Source Heat Pumps

In 2022, the 5 million Australian homes connected to the methane gas network accounted for 17% of total gas consumed in Australia (~5% of total methane production). The transition from gas to electrified heating, cooking and hot water systems is a critical component to achieving the nation's domestic emissions reduction targets and renewable energy targets, and this should underpin significant ongoing cost savings to consumers once the upfront capital costs are overcome.[71]

Not only is the transition to household electrification valuable to meeting large targets, electric homes are also significantly more energy efficient than gas alternatives, providing an additional cost saving avenue to Australian energy bills. An efficient gas heater can convert one unit of delivered energy into a maximum of one unit of heat, while electric heat pumps can produce 3-5 units of heat for the same energy input. In 2021, the Grattan Institute's analysis of Energy Consult (2021) found annual savings for households in Brisbane can reach $3,890. As fossil-fuel electricity and gas prices have continued to rise, switching to electric appliances powered by renewable energy has only further increased savings to consumers.

In 2023, 12,964 solar water heaters and air source heat pumps were installed in Queensland - Figure 3.9.[72] Cumulative installations across Queensland now exceed 348,000 as of 2023, 21% of all installations across Australia, behind Victoria (33%) and NSW (23%).[73]

Figure 3.9: Cumulative Solar Water Heater and Air Source Heat Pump Installations



Source: Clean Energy Regulator [74]

[71] Grattan Institute, Getting Off Gas: Why, How, and Who Should Pay?, June 2023
[72] Note: CER data includes new installations and upgrades to existing systems
[73] CER, Postcode Data for Small-Scale Installations, 16 January 2024
[74] CER, Postcode Data for Small-Scale Installations, 16 January 2024

Section 3.5. Home Energy Efficiency

Air-conditioning and heating represent a significant proportion of residential energy demand. Whilst improving the energy efficiency of appliances and installing reverse-cycle air-conditioning units will aid in reducing household demand, a key, and often overlooked component, is improving the home's thermal efficiency to reduce the reliance on artificial cooling in summer and heating in winter.

In August 2022, Building Ministers across Australia agreed to update the National Construction Code (NCC 2022) with new minimum energy efficiency standards. As part of the update, the Nationwide House Energy Rating Scheme (NatHERS), the guide to measure a home's energy efficiency, was expanded to meet the NCC 2022 updates, the biggest overhaul since the NatHERS scheme began in 1993.[75]

From 1 October 2023, the Queensland Government will phase in the National Construction Code 2022. From 1 May 2024, new builds in Queensland will be built to updated energy efficiency standards that ensure homes are warmer in winter and cooler in summer, reducing energy bills by ~ $185 a year.[76]

The amendments to NCC 2022 Volume One – Section J. Energy Efficiency were introduced for three reasons, to (a) reduce energy consumption and energy peak demand, (b) reduce greenhouse gas emissions, and (c) improve occupant health and amenity.[77]

A summary of key updates in energy efficiency, in which new builds must adhere to:

- J1F1 (e) – be able to accommodate the future installation of CERs,
- J1P2 – not exceed improved thermal energy load limits i.e. aggregation of energy required to heat and cool relative to area,
- J1P4 – have features that facilitate the future installation of on-site renewable energy generation and storage, and EV charging equipment,
- J9D3 (3) – be fitted with energy meters that are interlinked by a communication system that collates time-of-use data to a single interface monitoring system where it can be stored, analysed and reviewed,
- J9D4 – improved requirements for accessibility to EV charging based on building classification, as well as requirements of electrical distribution boards that can facilitate varied charging loads at different time periods over 24-hrs,
- Achieve an energy rating of 7 stars under NatHERS.

The Australian Building Codes Board (ABCB) expects the Modern Homes Standards will collectively add 1-2% to the cost of building new homes, with costs reducing over time as industry adjusts to the changes and domestic supply chains are modernised towards those that have been in place in Europe for at least a decade. Whilst improving the lifetime savings via energy bills, CSIRO estimates 7-star energy efficiency will increase a home's sale price by ~10%.

[75] DCCEEW, National Construction Code Updates Mean Energy Efficiency Ratings Expansion for New Residences, 29 August 2022
[76] QLD Gov, Queensland's Better Building Standards, 19 September 2023
[77] ABCB, National Construction Code: Volume One, 2022

Section 4. Demand Response Mechanisms

Grid stability and security are of paramount importance as the grid transitions from dispatchable fossil fuel generation to VRE. Grid firming solutions provide a vital solution to supplying peak demand periods. However, load shifting and demand response mechanisms are also a necessary component to achieving net zero. Financial incentives to shave peak demand and/or shift demand to periods of excess renewable generation or away from excess demand periods are vital to ensuring grid frequency stability. There are multiple opportunities for both residential and commercial applications of demand response.

As greater energy demand is met with VRE, our energy grid regulators and managers must adopt new tools to replace retiring dispatchable fossil fuel generation to maintain the balance of supply and demand for grid reliability and inertia. A key part of this solution is shifting energy demand to become more in-line with predictable periods of high solar and wind generation.

Demand response management (DRM) is the balancing of supply and demand in the power grid to periods where demand is lower, and where supply is in excess, using monetary incentives to induce structural changes to the way we consume electricity. DRM can be achieved using price-based programs, in which price signals and tariffs are used to encourage load-shifting, or incentive-based programs, in which payments are made to consumers who shift demand as part of a broader demand-side program.[78]

Simply, industrial demand response mechanisms can operate by firms signing up to reduce energy use in periods of excess demand. When electricity demand surges, users reduce their load, balancing supply and demand and stabilising grid frequency, and in return are paid for their involvement in meeting peak demand.[79]

A report by University of Technology Sydney's Institute for Sustainable Futures (UTS-ISF), commissioned by ARENA, identified that with greater flexibility with current commercial and residential technologies, in conjunction with high EV uptake and V2G, household electrification and high CER adoption, implementing load flexibility programs can achieve up to $18bn in cumulative savings to 2040.[80]

Stacking multiple energy services and revenue streams for participating industrial consumers is key to improving demand response as a whole and operating as a reliable component to peak demand. Industrial demand response mechanisms identified by ARENA include:

- **Emergency demand response:** payments for capacity or events contracted via the Reserve Emergency Reliability Trading (RERT) scheme.
- **Network demand flexibility**: payments to shift electricity consumption out of peak demand times to avoid or defer network upgrades.
- **Wholesale demand flexibility**: payments for availability of capacity or arbitrate to reduce consumption in high-price times and/or increase in low-price times.
- **Frequency Control and Ancillary Services** (FCAS): payments for fast-demand response to maintain frequency and voltage.

[78] IEA, Demand Response, updated 11 July 2023
[79] ARENA, How Demand Response Works, 15 July 2020
[80] ARENA, Knowledge Sharing Demand Flexibility Portfolio Retrospective Analysis Report, July 2023

ARENA has committed $180m to 55 demand response projects to demonstrate demand flexibility enabling technologies and approaches. ARENA has funded the largest number of projects within the **C&I sector**, however, has invested the largest value into **residential** load flexibility projects, funding $77m, or 43% of total funding.

Residential Demand Response

Through multiple residential demand response projects funded by ARENA, the largest opportunities for emergency demand response (load shedding) and peak demand shifting are:

- **Residential air-conditioning**: large opportunities for emergency response, peak demand and minimum demand services.
- **Residential hot water**: significant opportunities to shift heating into midday during periods of high solar generation and lower demand, with lesser opportunities in emergency and peak demand flexibility.
- **Residential pool pumps**: demand response operating similar to water heating, shifting load in line with periods of low-prices.
- **Commercial HVAC**: large-scale resource for switching off air-conditioning (load shedding) as emergency response, whilst utilising small adjustments in temperature settings in response to price signals.

Technical standards are a major barrier to unlocking residential demand flexibility. Demand response enabled residential **air-conditioning** devices (standard AS-4755) was identified as a key limitation. Although 170,000 air-conditioners are installed in QLD on PeakSmart meters [81], the majority of total air-conditioning stock is not capable of demand response, and most of Australia's $10 trillion of housing stock is very poorly sealed and insulated. Australia needs to mandate energy ratings on houses and apartments at the time of sale or lease. [82]

In addition, the absence of common interoperability standards across btm devices and **EV chargers** was identified as a barrier that needs to be resolved. Without standardisation, competition for surplus solar between devices can result in suboptimal outcomes for the consumer and energy system, with inefficient direction to water heating, storage and export into the grid.

Early **smart meters** don't necessarily contain the required software to maximise demand flexibility. The acceleration of intelligent smart meter deployment is critical to unlocking residential demand response programs. CEF supports the AEMC review's recommendations to accelerate the roll-out of smart meters to 100% coverage by 2030, which can then facilitate widespread adoption of time of day retail tariff structures, as well as solar tariffs.

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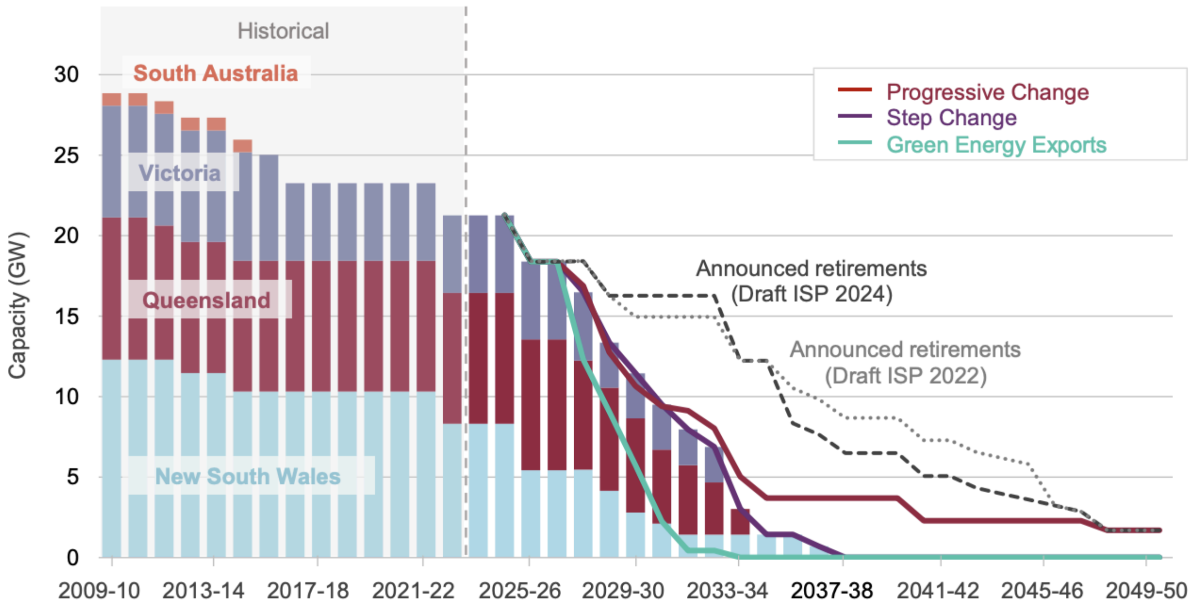
[81] ABC, Energex Remotely Cuts Power to 170,000 Air Conditioners Six Times in a Month, 31 January 2024
[82] The Guardian, Landlords should reveal homes' energy efficiency to help Australia's renters cut power bills, advocates say, 12 February 2024

Section 5. Phase-out of Coal-Fired Generation

Despite having a relatively young coal fleet, QLD's energy transformation is accelerating the phase-out of thermal power reliance. Despite accounting for 71% of net consumption in FY23, QLD's entire fleet will likely retire by FY35. The catastrophic failure of Callide C has highlighted the operational risk associated with over reliance on centralised, ageing assets. As renewables scale rapidly, the economic case for thermal power will continue to decline. AEMO forecasts QLD's coal plants will spend a significantly higher proportion of time at minimum load in FY30, at ~ 40% compared to today's 10%. QLD's comparative advantage in its state-ownership of coal plants means QLD can execute a smooth transition to firmed renewables without impact on grid strength and stability.

Ten coal-fired generators have retired over the last decade across the NEM. The 2024 Draft ISP forecasts the remaining coal fleet will close two- to three-times faster than currently scheduled announcements between now and 2051. Under AEMO's Step Change scenario, ~90% of the NEM's coal fleet is forecast to retire by 2034-35, with all generators retired by 2037-38 - Figure 5.1.[83]

Figure 5.1: NEM Coal Capacity Forecast



Source: AEMO 2024 ISP Draft [84]

Under the Step Change scenario, QLD will retire its entire coal fleet by 2034-35, in-line with QEJP's goal to have no regular reliance on coal generation by 2035. Historically, QLD has been exceptionally reliant on coal-fired generation in its electricity grid, with supply outpacing total state demand in the early 2000s, feeding the excess south into the NEM. Coal generation peaked at 105% of demand in FY2004. Thermal power remains the largest source of generation across the state, and contributed to 71% of FY23 total demand in QLD.

The transition from a centralised coal-dominant high emissions energy grid to a distributed renewable energy system will provide a great deal of benefits to both households and industrial consumers, as well as safeguarding the state's energy security from fuel

[83] AEMO, Draft 2024 ISP, 15 December 2023
[84] AEMO, Draft 2024 ISP, 15 December 2023

hyper-inflation and singular point of failure. On 25 May 2021, Callide unit C4 experienced a catastrophic failure, tripping other Callide B and C units. With a domino effect to substations, transmission lines and other generators, the explosion resulted in 400,000 customers losing power from Cairns to Gold Coast, sending electricity spot prices to the maximum $15,000/MWh to replace the 2000MW deficit.[85]

Following the collapse of Callide C4, its sister plant C3 experienced a structural failure, with two cells of its cooling plant collapsing in October 2022. The failures are expected to cost taxpayers ~ $400m to rebuild Callide C3 and C4. On 15 January 2024, operator CS Energy further extended C3 and C4's return horizon, delaying partial capacity return to C3 and C4 to 29 February 2024 and 30 June 2024 respectively;[86] more than 3-years since its explosion tripped the NEM.[87]

Similarly, the reconstruction of Western Australia's Muja AB power station perfectly highlights the costs borne by taxpayers for the reliance on end-of-life coal plants. Initially budgeted as a $150m renewal, it resulted in a cost blowout to $310m of public funding. Following recommissioning, Muja AB was plagued by operational and reliability problems, producing just 20% of the time. In September 2017, Synergy finally announced the permanent closure of Muja AB.[88] A startling result is that now the West Australian government plans to close all of its public owned coal fired power plants by 2030. Queensland currently has 8 coal-fired generators operating across the state, with a combined capacity of 8,119MW, as shown in Figure 5.2.

Figure 5.2: QLD Coal-Fired Power Plant Summary

Plant	Owner	Capacity MW	FY23 Gen. GWh	Capacity Factor	Demand contribution	Commissioned
Kogan Creek	CS Energy	744	4,480	68.7%	7%	2007
Callide B	CS Energy	700	4,199	68.5%	7%	1988
Callide C	CS Energy	840	1,038	21.2%	2%	2001
Tarong	Stanwell	1,400	9,404	76.7%	16%	1986
Tarong North	Stanwell	443	2,196	56.6%	4%	2003
Stanwell	Stanwell	1,460	9,365	73.2%	16%	1993
Millmerran	InterGen & China HuaNeng Group (CHG)	852	5,981	80.1%	10%	2003
Gladstone	Rio Tinto & NRG Energy	1,680	6,521	44.3%	11%	1976

Source: OpenNEM, CEF Calculations

[85] AFR, Shortfall Fears as Fire Rips Through QLD Power Station, 25 May 2021
[86] CS Energy, Update on Progress in Returning Callide C Power Station to Service, 15 January 2024
[87] Renew Economy, Return of QLD's Exploded Coal Plant Delayed Another 6 Months, 30 May 2023
[88] West Australian, Collie's Muja AB Power Station to Close in Multi-Million Dollar Loss, 14 September 2017

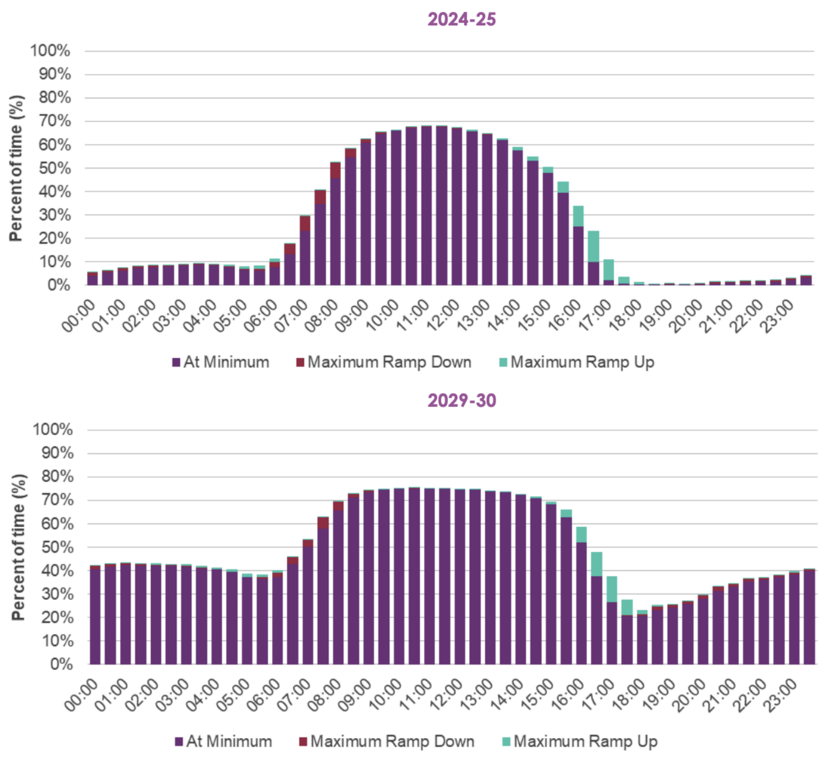
As part of the QEJP, the state aims to have no regular generation from coal-fired power plants by 2035. This will require the phase-out and replacement of 43TWh annual generation with zero-emission technology in the next 11 years.

Queensland's coal-powered fleet is majority state-owned, with CS Energy and Stanwell combined to an aggregate 5,587MW, or 69% of the dispatchable coal capacity across the state. The higher market share of state-owned assets provides QLD with a unique advantage to other NEM states, the ability to phase out and replace incumbent energy hubs with lower cost zero emissions renewable energy generation and storage, in-line with its soon to be legislated emissions reduction and renewable energy targets.

Ownership of aging thermal plants has become less attractive, with higher operating costs, reduced fuel security and high maintenance costs, a growing unwillingness of financial markets to refinance coal as well as rapidly increasing competition from lower-cost renewable energy in the wholesale market. As renewable energy generation comes online, with firming solutions providing a mechanism to dispatch zero-emission energy during periods of peak demand, coal-fired power plants will continue to reduce their output, operating at minimum load for longer intervals, further undermining the economics for coal generators, and furthering the advantage of adopting VRE and battery storage.

AEMO forecasts a significant uptick in the time spent at minimum load for Queensland's coal generators in the coming years, with off-peak time at minimum load rising from less than 10% to ~ 40% by 2030 - Figure 5.3. Peaking demand will be increasingly met by dispatchable battery storage, demand response management (DRM), methane gas peakers and PHS.

<u>Figure 5.3: Forecast Black Coal Percentage of Time Minimum Load and Maximum Ramp</u>



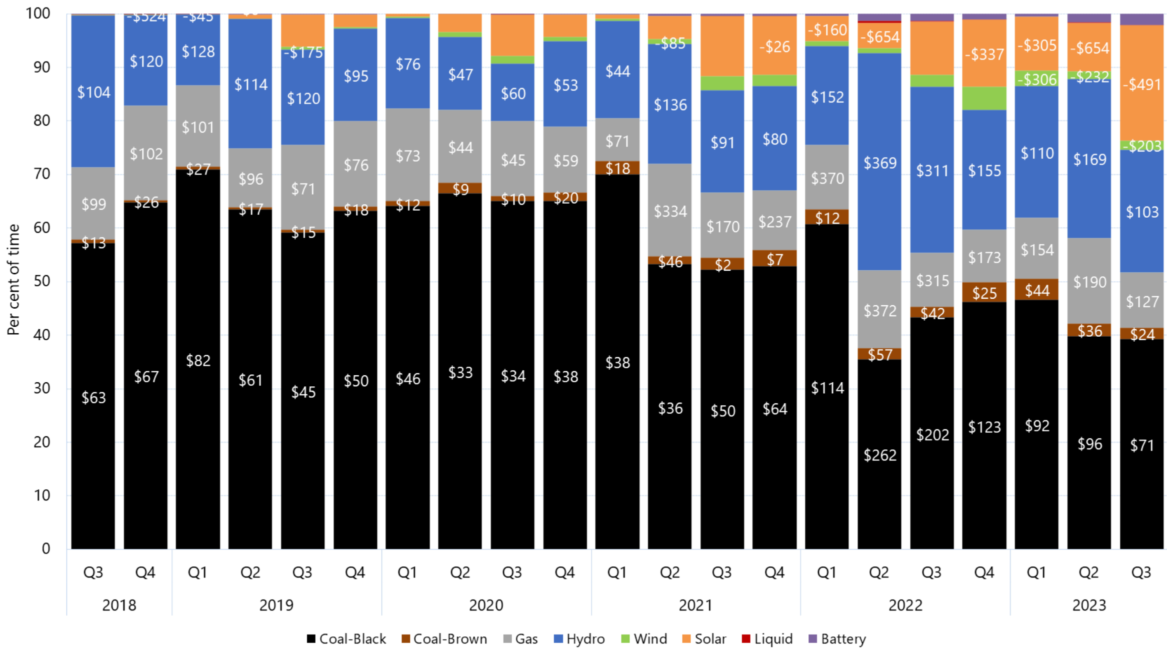
Source: AEMO Draft 2024 ISP Appendix 4. System Operability [89]

[89] AEMO, [Draft 2024 ISP Appendix 4. System Operability](), 15 December 2023

The incredible growth of utility-scale and distributed rooftop solar PV across the state has resulted in legacy coal generators losing their ability to dictate the wholesale market.

In 3QCY2023, black-coal (all QLD coal is black (i.e thermal as opposed to lignite)) were the wholesale price setters for a near-low 40% of the time. Compared to just 3-years prior, where coal dominated the wholesale market, dictating prices 60-70% of the time. In 3QCY2023, solar reached its highest penetration in QLD's grid, setting the wholesale prices near 20% of the time, with an average of **negative** $491/MWh - Figure 5.4. This highlights how battery energy stationary storage (BESS) is increasingly financially enabled to shift solar power into the higher value evening peak, which in turn will undermine the economic value of methane gas powered peaking plants.

<u>Figure 5.4: QLD Quarterly Price Setter and Average Price by Fuel Source</u>



Source: Australian Energy Regulator [90]

Through the QEJP, the state government will invest to repurpose public-owned coal-fired power plants into clean energy hubs, leveraging existing workforces, strong existing transmission networks and associated infrastructure.

Under the Plan, currently-operating coal plants will phase-out via a systematic and controlled reduction in generation, going from (1) fully generating assets, to (2) operating seasonally as reserve power, removing one or more units, then (3) operating as synchronous condensers, providing system strength and inertia through the import of small amounts of energy, with no generation, to finally (4) decommissioning and replacement - Figure 5.5. Operating as hubs of renewable energy generation and storage for a decarbonised grid.

The stages of CS Energy and Stanwell power plant conversion are as follows:

1. **Phase 1** – gradual shift to seasonal operation or synchronous condenser conversion for one or more units from 2027 plus maintain thermal generation in 'reserve' as back up capacity.

[90] AER, Quarterly Price Setter and Average Price Set by Fuel Source - QLD

2. **Phase 2** – Once PHS is online, further conversion to seasonal operation and reversible conversion to synchronous condenser (except Callide B with scheduled retirement in 2028).
3. **Phase 3** – Once both PHS projects online, further conversion to synchronous condensers.

Figure 5.5: Transformation of Coal-fired Plants to Synchronous Condensers

Power Station	22-23	23-24	24-25	25-26	26-27	27-28	28-29	29-30	30-31	31-32	32-33	33-34	34-35	→
Stanwell (4 units)	No Change				Phase 1			Phase 2			Phase 3			
Tarong & Tarong North (5 units)	No Change				Phase 1			Phase 2				Phase 3		
Callide B (2 units)	No Change				Phase 1	Phase 2	Phase 3							
Kogan Creek (1 unit)	No Change												Phase 1	Phase 3
Large-scale Renewable Capacity (total)		5.2	5.6	6.2	7.7	8.7	9.9	12.7	13.6	15.4	19.4	24.4	25.0	→
Dispatchable Capacity (total)		13.2	13.3	14.0	14.0	13.6	13.5	14.8	13.7	14.3	16.0	15.8	15.7	→
Peak Demand		10.3	10.4	10.7	10.9	11	11.1	11.3	11.5	11.7	11.7	12.0	12.1	

Source: QLD Energy and Jobs Plan [91]

AEMO's draft 2024 ISP highlighted four main risks across both market and policy settings for the accelerated phase-out of coal. Mainly, whilst coal-fired generators have announced long-term retirement plans, generators only legally have to provide 3.5 years' notice of closure (and even this is unreliable given the growing experience of coal plant catastrophic failures). Thus, as the financial case for the continued operation of coal-fired power plants weakens, QLD is moving to pre-empt and avoid the risks of short-term reliability challenges and price shocks to consumers.[92]

Given the state-ownership of thermal power plants, QLD can execute a smoother transition to firmed renewables and manage the impact on grid strength and stability. Given the significant scaling of public financing via the QEJP, QLD is investing in upgraded transmission networks, renewable energy generation and storage projects, as well as crowding in the private sector via contracted renewables and long-term PPAs to de-risk projects for developers.

Further, the accelerated aggregation and coordination of CERs into VPPs will provide system reliability and security to QLD's grid, further shifting the financial benefits of renewable energy onto customers, and easing the reliance on utility-scale projects to power the entirety of QLD's demand.

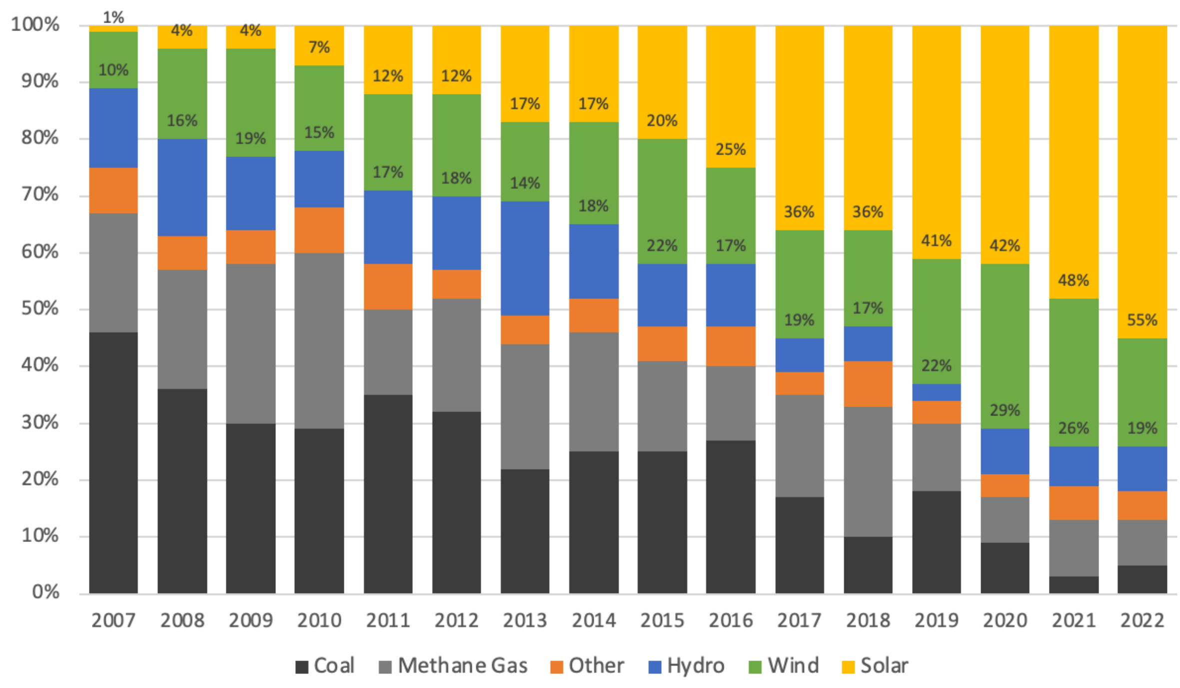
[91] QLD Government EPW, Queensland Energy and Jobs Plan, September 2022
[92] AEMO, Draft 2024 ISP, 15 December 2023

Section 6. Large-scale Wind and Solar Capacity

QLD Energy and Jobs Plan forecasts 25GW of renewable capacity is required to replace the 8GW of retiring coal capacity to ensure a stable and reliable grid. AEMO forecasts ~ 46GW of new utility-scale wind and solar will be required to replace all fossil fuel generation and early VRE across QLD by 2050. QLD has 9 potential REZs in development, the largest are in the North Queensland Clean Energy Hub, unlocked by CopperString 2032, and in the Darling Downs, where the largest operating wind and solar farms across the state are located. QLD has a total renewable potential of over 50GW of solar capacity, and over 42GW of wind capacity across all 9 potential REZs. AEMO's database has over 41GW of new wind and solar projects in the development pipeline.

World governments have allocated a combined US$1.34 trillion to clean energy since 2020.[93] Solar and wind capacity additions continue to outpace new fossil fuel generation, with solar accounting for 55% of all additions in 2022. Combined with investments in wind capacity, VRE accounted for 74% of all new electricity generation assets globally in 2022 - Figure 6.1.

Figure 6.1: Global Capacity Additions by Generation Source



Source: BloombergNEF, Michael Liebreich

World leaders like China have demonstrated the speed and scale at which renewable energy generation can be deployed with coordinated and efficient energy policies that crowd in investment. In CY2023, China added 293GW of VRE capacity, 81% of all new domestic installations.[94] In the month of December alone, China added 80GW of VRE capacity, three times the targeted capacity of new wind and solar installs for Queensland by 2035.

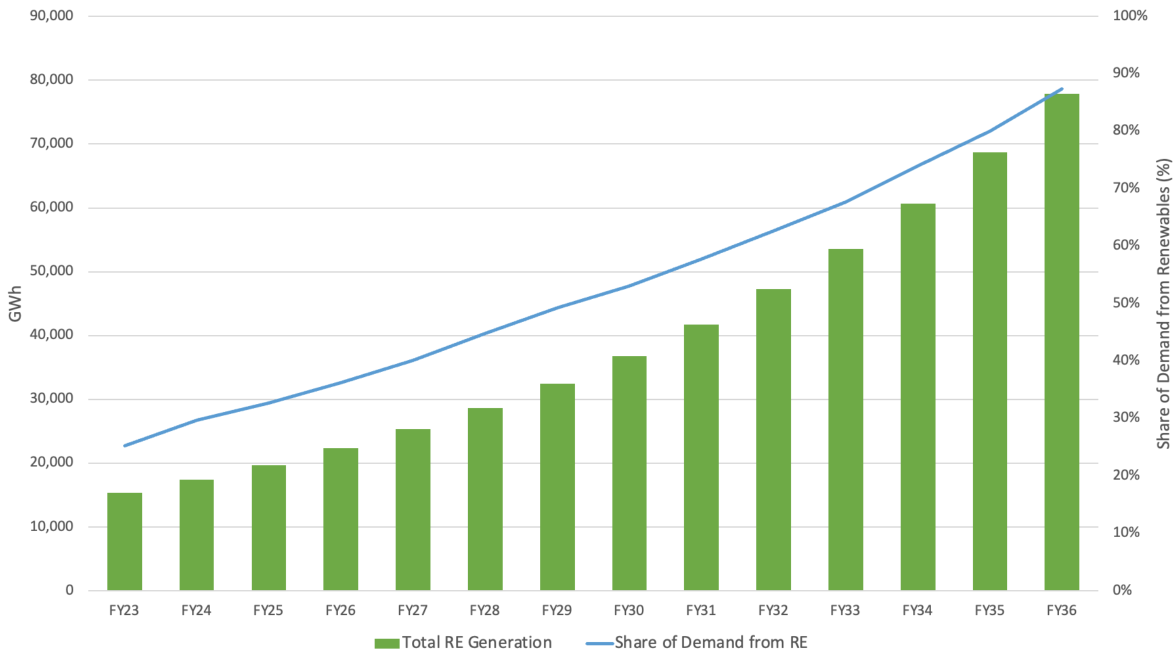
Due to the variable nature of wind and solar, significantly greater capacity of renewable energy generation is required to replace the dispatchable capacity of QLD's coal fleet. Under

[93] IEA, Governments are Continuing to Push Investment into Clean Energy, 2 June 2023
[94] CEF, Monthly China Energy Update, 30 January 2024

QLD Government's modelling, produced by Ernst & Young, large-scale solar farms, generally, have a maximum potential annual capacity factor of 25-33% i.e. solar generators produce, on average, between 25-33% of their nominal capacity. Wind has a higher annual capacity factor than solar, typically between 32-53%. To meet current maximum demand of 11GW[95], Queensland will require a minimum of 24,000MW of installed VRE generation capacity, with a combined annual capacity factor of 33% for wind and solar. This is equivalent to annual output of 8000MW of coal-fired capacity.[96]

In order to meet QLD's 80% target by 2035, renewable energy must generate 68.7TWh under AEMO ESOO 2023 Central Scenario. This will require zero-emissions generation to grow at 13.3% CAGR to supply 80% of AEMO's forecasted demand by FY35 - Figure 6.2.

Figure 6.2: Renewable Energy Generation Required to Hit 80% RE Target – ESOO Central



Source: AEMO and OpenNEM, CEF Calculations [97]

Energy generation from renewables in Queensland has continued to grow. In the 5-years to FY23, renewable energy has gone from 6.1% of demand in FY18, to 25% in FY23, driven largely by distributed rooftop solar PV and utility-scale solar. Significant new renewable capacity has come online over the past 24 months, with 1HFY24 reaching a record 30% of total demand supplied by renewables.

[95] Powerlink, New Record in Queensland's Peak Demand for Electricity, 22 January 2024
[96] QLD Government EPW, Queensland SuperGrid Infrastructure Blueprint, September 2022
[97] AEMO, 2023 QLD ESOO Central Forecast Annual Consumption, 31 August 2023

Section 6.1. Existing Utility-Scale Renewable Capacity

In 2023, renewables generated 17,564GWh of electricity in Queensland, contributing to 28.2% of state demand. Of that, utility-scale solar supplied 9.4% to state demand, followed by wind at 4.2%. In 2023, ~ 2.36GW of utility-scale solar and ~ 1GW of wind capacity was **operating** across Queensland. For large-scale VRE, Queensland currently has 3.38GW of capacity, with new capacity undergoing commissioning in 2HCY23.

Western Downs Green Power Hub

Neoen is the largest renewable energy provider in Australia, with a total of 3.3GW of capacity in operation and under construction, 2GW of which are generating assets, and 1.3GW/2.8GWh is storage capacity. Neoen's assets represent 10% of Australia's utility-scale solar, 10% of wind capacity, and 45% of grid-scale battery energy storage system (BESS) capacity.

Neoen has invested over $4bn into generation and storage assets across Australia to date. Most recently, commissioned in the first half of 2023, the $600m Queensland Western Downs Green Power Hub is the largest operating solar farm in Australia.

Neoen completed construction of the 460MWp solar farm in April 2023, with over 1 million panels installed across 1,500 hectares (ha).[98] The farm is positioned 22km south-east of Chinchilla, and connected just 6km to Powerlink's Western Downs substation via a new 275kV transmission line. This will allow the Western Downs Hub to generate over 1,068GWh of electricity, equivalent to powering 235,000 homes across Queensland from zero-emissions solar. Since commissioning mid-year, and ramping up production, Western Downs has generated over 648GWh into the energy market.

The solar farm is also positioned in close proximity to the QLD/NSW Interconnector (QNI), allowing marketable renewable energy to be exported to other NEM states to help decarbonise Australia's energy demand.

The development of Western Downs was supported by a 10-year PPA with state government-owned generator, **CleanCo**.[99] The PPA represents ~ 80% (352MWp) of the solar farm's output, underwriting the revenue for Neoen over the next decade. Western Downs long-term PPA has been in place since April 2023.[100] In 2020, CleanCo and Coles signed a 10-year contract to power over 90% of its Queensland sites from July 2022 with renewable energy. The 10-year PPA between CleanCo and Neoen will power the deal with Coles.[101]

Columboola Solar Farm

Columboola is a 162MW solar farm, located 10km northeast of Miles in the Western Downs region. Columboola is owned by South Korean investment manager **Hana Financial Investment**, acquiring the project from Luminous Energy. The project was funded by $120m equity from Hana, supported by a $200m debt facility from ANZ, Singapore's DBS, and French investment bank Societe General.[102]

[98] PV Magazine, Final Panel Installed as Australia's Largest Solar Farm Nears Full Capacity, 6 April 2023
[99] PV Magazine, Neoen to Build Australia's Largest Solar Farm After Power Deal with CleanCo, 6 May 2020
[100] Neoen, Nine-month 2023 Revenue, 2 November 2023
[101] PV Magazine, Australia's Biggest Solar Farm to Supply Power to Supermarket Chain, 5 December 2023
[102] Renew Economy, Hana Seals Finance for First Australian Solar Farm, 15 September 2020

Columboola comprises 410,000 bifacial solar panels on single-axis trackers across 410 ha. At full capacity, the farm will generate 440GWh annually.[103] The farm began generation ramping at the beginning of 2023.[104]

In August 2020, **CS Energy** signed a long-term PPA with Columboola, purchasing 100% of the farm's output over 10-years, on-selling to large C&I customers across Queensland via long-term contracts. CS Energy signed its major 10-year PPA with a group of universities including Griffith, CQUniversity, and QUT. The contract will provide 50% of Griffith University's electricity demand, reducing its total annual carbon footprint by 35%.

CS Energy signed an additional PPA with investment manager AMP Capital to source 100% of electricity demand of four major shopping centres in Queensland from renewable energy generated from the Columboola Solar Farm. The PPA with AMP Capital is a 7-year deal, supplying 94GWh annually, marking the contract as the first 100% renewable energy deal of CS Energy's now expanding contracted renewables portfolio.[105]

Edenvale Solar Park

Edenvale is a 204MW solar farm 20km northeast of Chinchilla. Edenvale is a 50:50 joint venture (JV) between Sojitz Corporation and ENEOS Australia, operated by Gransolar Group (GRS). Both Sojitz and ENEOS are Japanese multinationals, with major involvements in global petrochemicals. Edenvale represents the largest solar asset investment by Japanese companies in Australia.

Construction began in June 2021, with initial production expected 1QCY2023. The park was officially commissioned on 28 September 2023. [106] The farm covers 428 ha. 70% of the farm's output will be sold to an undisclosed energy retailer via a long-term fixed-price PPA. The remaining 30% will be directed to Sojitz's Gregory Crinum coal mine in Queensland.[107]

The investment into Australian renewable energy generation from Japanese multinationals is the early stages of developing a green hydrogen supply chain to Japan. In January 2023, ENEOS announced it had constructed a green hydrogen demonstration plant in Brisbane's Bulwer Island.[108]

Daydream Solar Farm

Daydream is a 150MW solar farm north of Collinsville in North Queensland. Daydream was constructed, and is owned and operated, by **Edify Energy**. Commissioned in August 2018, Daydream consists of 1.5 million single-axis tracking solar panels, generating 396GWh pa.[109]

In August 2017, **Origin Energy** signed a long-term PPA for 100% of the output from Daydream until 2030, including Renewable Energy Certificates (RECs) as part of Origin's commitment to source 25% of generation mix from renewables by 2020.[110] The long-term

[103] PV Magazine, Sterling & Wilson Switches on 162MW Solar Plant in Australia, 7 December 2022
[104] OpenNEM, Queensland Facilities – Columboola Solar
[105] PV Magazine, CS Energy Continues Transition with First 100% Renewable Energy PPA, 6 February 2023
[106] PV Magazine, Japanese-owned 204MW Solar Park Commissioned in Queensland, 3 October 2023
[107] PV Magazine, Japanese Duo Team Up to Build Queensland Solar Farm, 11 June 2021
[108] QLD Government, Japanese Investment Backs Queensland as Global Hydrogen Powerhouse, 1 February 2023
[109] Edify Energy, Daydream Solar Farm
[110] Renew Economy, Origin Signs PPA for new 150MW Solar Farm in North Queensland, 10 August 2017

offtake underpinned the development of Daydream. Daydream connects to the 275kV Strathmore substation, via a new dedicated 275kV transmission line built by Powerlink.

Edify Energy has a portfolio of solar assets in the Collinsville region, including the 57.5MW Whitsunday solar farm. Whitsunday has been operational since March 2018, capable of supplying 144GWh pa of electricity. Whitsunday was constructed following a 20-year PPA with the Queensland Government.

In March 2017, alongside the long-term state government PPA, Edify locked in a $230m financing package from major lenders including CommBank, Clean Energy Finance Corporation (CEFC) and Germany's NORD/LB, in addition to grant funding from ARENA.[111]

The debt facilities provided the financing for Whitsunday and Hamilton – an identical 57.5MW sister solar farm in Collinsville. The facility was also directed to Edify's 50MW Gannawarra solar farm in Victoria, which was underpinned by a 13-year PPA with EnergyAustralia.

Edify also operates the 57.5MW Hamilton solar farm adjacent to Hayman, Daydream and Whitsunday. Hayman and Hamilton's generation is sold into the grid on a merchant basis. Combined, Edify has an aggregate 322.5MW of utility-scale solar generation across the Collinsville region.

Figure 6.3: Edify Energy Collinsville Solar Hub

Asset	Capacity MW/MWp	Annual Output GWh	Generation equivalence	Customer / PPA
Daydream	150	396	68,704	Origin Energy 100% 12-year PPA
Hayman	57.5	144	31,000	QLD Gov 100% 20-year PPA
Whitsunday	57.5	144	31,000	Wholesale market
Hamilton	57.5	144	31,000	Wholesale market

Wandoan South

In October 2022, **Vena Energy** reached financial close on the 125MW Wandoan South Solar Project.[112] The plant covers 500 ha, capable of producing up to 365GWh annually. Wandoan South was operationalised in February 2024.

Wandoan solar farm is the first major solar farm to be added to a grid-scale BESS. The Wandoan South BESS is the largest grid-firming battery in Queensland, discussed further in Grid Firming Solutions – Batteries (Section 7.1) below. Vena Energy is planning to expand Wandoan South to up to 650MW of solar capacity in the future.[113]

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[111] Edify Energy, Government, CBA in Landmark $230m Solar Deal, 13 March 2017
[112] Vena Energy, Vena Energy Achieves Financial Close on Wandoan South Solar Project, 12 October 2022
[113] Renew Economy, First Major Solar Farm to be Added to Big Battery Starts Operations, 29 May 2023

Sun Metals Solar Farm

Korea Zinc Co. is the largest zinc, lead and silver producer in the world. Its Australian subsidiary, **Sun Metals**, has operated the Sun Metals Zinc Refinery in Townsville since 1996. Sun Metals is the second-largest single-site consumer of electricity in Queensland. Sun Metals made the commitment to produce green zinc, powering its entire operations from 100% renewable electricity by 2040, with an interim target of 80% by 2030.[114]

In 2018, Sun Metals invested $200m to construct the 143MW Sun Metals Solar Farm, a 1.26 million module system capable of supplying a third of the refinery's energy demand at the time. It is the largest integrated industrial-used solar farm in Australia. Since Sun Metals' expansion, the solar farm accounts for ~ 22% of the refinery's energy demand.

Coopers Gap Wind Farm

Coopers Gap is a 453MW Wind Farm between Dalby and Chinchilla. When construction was completed, it was the largest wind farm in Australia. It remains the largest wind farm in Queensland currently. Construction began in September 2017, with first generation in June 2019. After full capacity commissioning in March 2023, Coopers Gap is able to produce 1,515GWh annually.[115]

Coopers Gap was developed by Powering Australian Renewables Fund (PARF, then PowAR), a JV between Queensland Investment Corporation (QIC) – a QLD Government owned investment and institutional manager, the Future Fund and AGL. The JV is split 40:40:20 respectively. The wind farm was built in partnership with GE Electric, supplying 91 3.6MW turbines and 32 3.8MW turbines.[116]

In August 2017, AGL reached financial close on the sale of Coopers Gap Wind Farm to Tilt Renewables. However, in March 2021, Powering Australian Renewables (in which AGL holds a 20% stake) acquired 100% of Tilt Renewables Australia.[117] Tilt Renewables' existing assets merged with PowAR's under a consolidated entity. PowAR then rebranded to **Tilt Renewables**. AGL purchases 100% of the wind energy generated from Coopers Gap via a long-term PPA. Coopers Gap has steadily ramped up production since its first generation in 2019, producing 1,414GWh in FY23 and 1,352GWh in FY22.[118]

Dulacca Wind Farm

Dulacca is the latest wind farm to be developed in Queensland. In October 2023, **Octopus Australia** opened the 180MW wind farm 250km west of Toowoomba in the Western Downs region of Queensland. Despite the site covering ~ 8,000 ha, only ~ 2% of total land is used by the wind turbines, allowing Dulacca to co-exist with the existing agricultural use of the land.[119]

Dulacca was developed by RES Australia, which sold ownership to Octopus Australia in 2021. Dulacca consists of 43 4.2MW turbines, supplied and installed by Vestas, which are the tallest installed in Australia, standing at 250 metres from base to tip.[120]

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[114] Sun Metals, Renewables
[115] Tilt Renewables, Coopers Gap Wind Farm
[116] GE Electric, GE and AGL Develop Australia's Largest Wind Farm in Coopers Gap, 17 August 2017
[117] AGL, AGL to Participate in PowAR's Acquisition of Tilt Renewables' Australian Business, 15 March 2021
[118] OpenNEM, Coopers Gap Wind Farm
[119] Dulacca Wind Farm, Renewable Energy Project: Dulacca Wind Farm
[120] Renew Economy, Last Massive Turbine Goes Up at QLD Wind Farm, 8 December 2022

State-owned **CleanCo** signed a long-term PPA with Octopus Australia to acquire 70% of the output (126MW), on-selling to customers including BHP Mitsubishi Alliance (BMA) and Scentre Group, which owns and operates QLD's Westfield shopping centres.[121]

Dulacca Wind Farm has begun ramping up production, generating over 210GWh in 2HCY2023, already surpassing a 32% capacity factor.

Mt Emerald Wind Farm

Mt Emerald was the first large-scale wind farm to be built in Queensland. RATCH-Australia reached financial close in November 2016 on the $380m 180MW wind farm, receiving financing from ABZ, NAB, Societe Generale and the Mitsubishi UFJ Financial Group.[122]

The wind farm comprises 53 Vestas turbines (37x 3.45MW and 16x 3.3MW). Since full operations in 2019, Mt Emerald has averaged over 420GWh annually, generating its best output of 491GWh in 2023.

In 2018, Powerlink built a dedicated 275kV substation near Mareeba for the Mt Emerald wind farm, connecting to the Woree to Chalumbin transmission network. Powerlink will maintain the substation with a 25-year power connection agreement.[123]

100% of the electricity generated is directed to Ergon Energy, which offered a 12.5-year PPA to RATCH-Australia until 2030.[124] The QLD Government confirmed the long-term offtake agreement with Ergon Energy and RATCH-Australia in November 2016.[125]

Kaban Wind Farm

The 157MW wind farm is a part of the Kaban Green Power Hub, located 80km southwest of Cairns, built by **Neoen**. Neoen completed construction of the $373m wind farm in August 2023, consisting of 28 turbines supplied by Vestas, able to generate 457GWh annually.[126]

The Kaban wind farm is a cornerstone project of the Northern Queensland REZ, connecting to QLD's SuperGrid via an upgraded 275kV (from 132KV) transmission line from the North Queensland coastal circuit, from Cairns to Townsville.

In October 2020, **CleanCo** signed a long-term PPA for 70% of generational capacity (110MW) from Kaban.[127] Neoen began ramping up production of Kaban in May 2023, and has now generated over 314GWh in 2023, with October and November both exceeding 42% capacity factors.

Section 6.2. New Utility-Scale Renewable Capacity

With AEMO's draft 2024 ISP estimates, ~ 46GW of new utility-scale wind and solar capacity is forecast as being required by 2050 to assist in replacing retiring generation of fossil fuels

[121] QLD Government, Dulacca Wind Farm Powers Up for Queensland, 18 October 2023
[122] Renew Economy, Queensland's First Large-scale Wind Farm Reaches Financial Close, 2 November 2016
[123] Powerlink, Mt Emerald Wind Farm Connection Project
[124] Renew Economy, Ergon Offers 12.5-year PPA with 180MW Wind Farm, 26 May 2016
[125] QLD Government, All Turbines Turning for Mount Emerald Wind Farm, 2 November 2016
[126] Powerlink, Kaban Green Power Hub Connection Project
[127] Neoen, CleanCo QLD Sign a New PPA for 110MW, 5 October 2020

and early VRE across QLD and meet demand growth.[128] AEMO expects the Darling Downs to see the largest capacity of new VRE, exceeding 5.7GW by 2032-33, and ~ 10GW by 2041-42.

The development of REZs is critical for Queensland and Australia to realise its renewable energy targets, coordinating necessary transmission investment to connect new generation and firming solutions. The 2024 draft ISP provides a scorecard of 43 potential Renewable Energy Zones across Australia, 9 of which are in Queensland. Under AEMO's modelling, QLD has the potential for ~ 93GW of renewable energy capacity, not all of which is economic or will be built - Figure 6.4.

Figure 6.4: Renewable Energy Potential Capacity in QLD REZs

Renewable Energy Zone	Renewable Potential (MW)		
	Solar	Wind	Total
Q1. Far North QLD	1,100	2,800	3,900
Q2. North Queensland Clean Energy Hub	8,000	18,600	26,600
Q3. Northern QLD	3,400	0	3,400
Q4. Isaac	6,900	3,800	10,700
Q5. Barcaldine	8,000	3,900	11,900
Q6. Fitzroy	7,533	3,500	11,033
Q7. Wide Bay	2,200	1,100	3,300
Q8. Darling Downs	6,992	5,600	12,592
Q9. Banana	6,100	3,400	9,500
Total QLD Potential	**50,225**	**42,700**	**92,925**

Source: Draft ISP 2024 Appendix 3. Renewable Energy Zones [129]

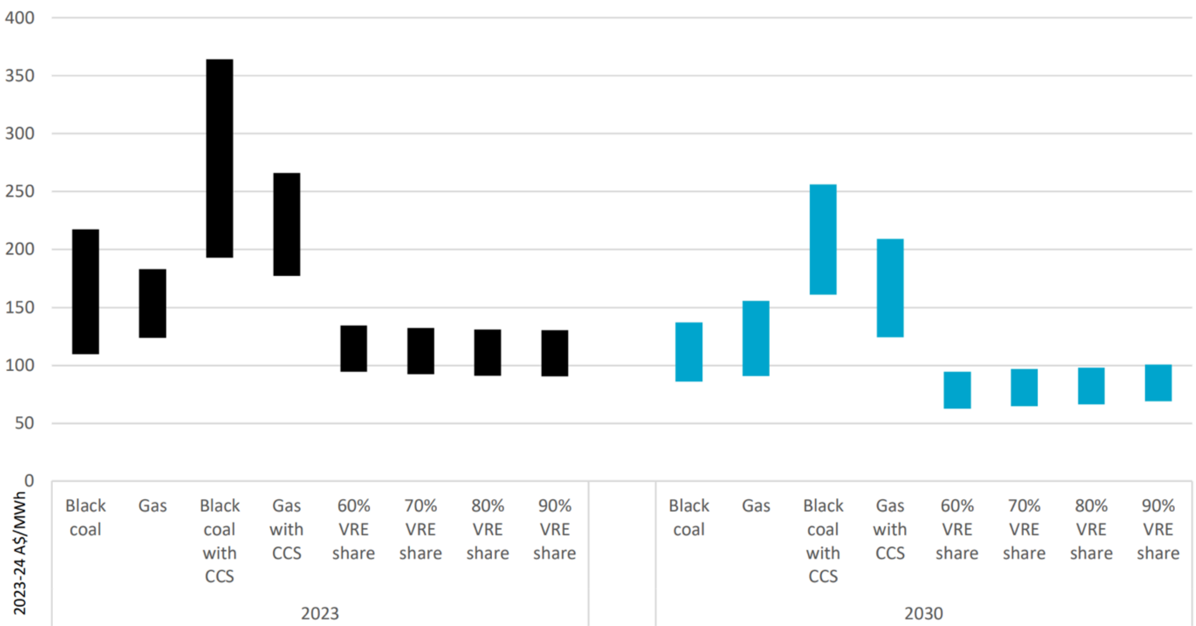
AEMO's Generation Information dataset showcases a significant volume of new wind and solar proposals for Queensland. AEMO's Generation Information pipeline is survey-based, but updated to be consistent with the Key Connection Information (KCI). For a program to meet KCI requirements, a connection inquiry must be made with a Transmission Network Service Provider (TNSP), e.g. Powerlink in QLD, which comes at a cost, and requires site location, maximum power and nameplate capacity.

From October 2023, AEMO's estimates 478MW of utility-scale solar either under construction or soon to be commenced, as well as **17,897MW** of solar proposals. For onshore wind, AEMO estimates 1,625MW in development, with a further **23,153MW** of onshore wind proposals. Combined, this is **41GW** of new wind and solar capacity in the investment pipeline to date across QLD, showing there is no shortage of investor interest and capital available once sensible grid T&D and approval plans are put in train.[130]

[128] AEMO, Draft ISP 2024 Appendix 3. Renewable Energy Zones, 15 December 2023
[129] AEMO, Draft ISP 2024 Appendix 3. Renewable Energy Zones, 15 December 2023
[130] AEMO, Generation Information October 2023, 2 November 2023

CSIRO's 2023-24 GenCost draft report continues to highlight the deflationary nature of deploying VRE technology. Even factoring in the additional integration cost of storage and upgraded transmission networks, the LCOE of variable renewables with integration costs is the lowest of all new-build technologies in both 2023 and 2030, even before methane and carbon emissions are priced in - Figure 6.5.[131]

Figure 6.5: CSIRO GenCost LCOE 2023 and 2030 Comparison



Source: CSIRO GenCost 2023-24 Draft [132]

Bulli Creek

ASX-listed renewable energy developer, **Genex Power**, is developing the multi-stage Bulli Creek green energy hub, a precinct of up to 2GW of utility-scale solar PV and BESS. The first stage, a 4-hour 400MW/1,600MWh BESS, followed by a solar park of up to 775MW.[133] Genex purchased the development rights of the Bulli Creek project from Solar Choice.

The project's scale is supported by the adjacent (4km) Powerlink Bulli Creek substation – the connection point to the QNI, with existing 330kV transmission lines. Genex has secured land options, as well as Development Approval and Environment Protection and Biodiversity Conservation Approvals. Financial close is expected in 2HCY2024.[134]

As demonstrated in the section above, Queensland's largest existing solar projects had existing long-term PPAs in place before construction, expediting FID and accelerating development by de-risking the project via guaranteed future revenue streams.

On 9 October 2023, Genex announced a long-term PPA with **Fortescue** for 337.5MW from the proposed Bulli Creek Solar (BCS) project. The PPA will secure energy generated from BCS at a nominal fixed price over 25-years, underwriting the future revenue stream of a

[131] CSIRO, GenCost 2023-24 Draft, 20 December 2023
[132] CSIRO, GenCost 2023-24 Draft, 20 December 2023
[133] Renew Economy, Genex Names Contractor for First Stage of Grid's Biggest Solar and Battery Project, 1 February 2023
[134] Genex Power, Bulli Creek Clean Energy Project

significant portion of first stage capacity. The PPA is conditional on Genex reaching financial close by 2HCY2024 on a minimum first stage capacity of 450MW, followed by the 400MW/1,600MWh BESS. This would result in first energy production expected in 2026.[135]

The off-take agreement aims to power a portion of Fortescue's ground breaking Gibson Island green hydrogen and green ammonia project proposal, which is still conditional upon yet-to-be allocated government financial support to bridge the absence of a CO2 price in Australia.[136] Genex CEO, Craig Francis, confirmed the PPA was bundled with green certificates including Large-scale Generation Certificates (LGC) until 2030. [137] The PPA would cover ~ 20% of the expected energy demand of Gibson Island, with a production of 385,000 tonnes per annum (tpa) of green ammonia.[138]

Smoky Creek

Edify Energy, which owns and operates the Daydream solar farm and the surrounding Collinsville solar precinct in Queensland, is developing the 600MW Smoky Creek wind farm, set to be located 40km north of Biloela in Central QLD.

The 600MW solar farm in development would provide sufficient energy to power 1,194GWh per annum. Smoky Creek would feed straight into Powerlink's Calvale substation, directing renewable energy into Stanwell's 275kV transmission lines.[139]

In October 2023, Edify Energy received developmental approval by Federal Minister for Environment and Water, Tanya Plibersek. The Federal Government approval was the last approval process required, with support from the local Banana Shire Council received several years prior.[140]

Edify Energy is also developing the 400MWp **Majors Creek** solar farm south of Townsville, QLD. Currently, Majors Creek's estimated capacity could produce 532GWh annually.[141]

Munna Creek

Greek energy firm, **Mytilineos**, is developing the 150MW Munna Creek solar farm located 40km northwest of Gympie, comprising of 375,000 solar modules on single-axis trackers.

In September 2023, Australia's communications giant, **Telstra**, signed a long-term PPA with Mytilineos for 50% of generated electricity from the Munna Creek solar farm.[142] The deal marks Telstra's 5th PPA for Australian renewable projects, including the 70MW Emerald Solar Park in QLD, and the major MacIntyre Wind Farm in southeast QLD, discussed further below.

Mytilineos has also secured a second offtake agreement with **NBN Co.**, the Australian Government-owned national broadband wholesaler, for a further 20% of the output.[143]

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135 Genex Power, Genex Secures Long-term 337.5MW offtake with Fortescue for BCS, 9 October 2023
136 Fortescue, Fortescue Enters Renewable Power Purchase Agreement, 9 October 2023
137 Renew Economy, Genex to Build Australia's Biggest Solar Farm After Supply Deal with Fortescue, 9 October 2023
138 AFR, Fortescue Hunting More Green Energy after Signing 25-year Supply Deal, 9 October 2023
139 Edify Energy, Smoky Creek Solar Power Station
140 PV Magazine, 600MW Solar Farm in Central Queensland Finally Secures Approval, 2 October 2023
141 Edify Energy, Majors Creek Solar Power Station
142 PV Magazine, Telstra Signs Offtake Deal with 120MW QLD Solar Farm, 28 September 2023
143 Mytilineos, Mytilineos has Secured Two PPAs for Munna Creek Solar Farm in Australia, 28 November 2023

Mytilineos also developed the 82MW (110MWp) Moura Solar Farm, which began energy production in late 2022.[144] State-owned **CS Energy** signed a long-term PPA with Mytilineos for 70% of the output from Moura, adding to its growing portfolio of contracted renewables.[145] Since full commissioning in June 2023, Moura solar farm has generated over 64GWh.[146]

Aldoga Solar Farm

Spanish developer **Acciona Energia**, has greenlit the $500m 380MW Aldoga solar farm, 20km northwest Gladstone. Construction will begin in 1QCY2024, and is expected to be built in 18 months.[147]

In October 2023, Stanwell Co. signed a 15-year PPA for 100% of the output from Aldoga, which will be used to power Queensland's largest proposed renewable hydrogen project, CQ-H2.[148]

MacIntyre Wind Farm

The MacIntyre wind precinct is the largest wind farm under construction both in Australia, and the southern hemisphere, and will be one the largest farms in the world on completion. With a total investment exceeding $1.96bn, the combined 1,026MWh precinct would comprise of the 923MW MacIntyre wind farm and 103MW Karara wind farm.[149]

The 923MW component is a JV between **Acciona** (70%) and **Ark Energy** (30%), the subsidiary of Sun Metals and Korea Zinc tasked at decarbonising the consolidated group's entire energy demand. Construction began in May 2022, and is expected to be operational by 2025. The wind farm will consist of 180 5.7MW turbines from Nordex, which merged with Acciona in 2016.

MacIntyre's development was underwritten by three main long-term energy off-take agreements with **CleanCo**, **Stanwell** and **Telstra**. In October 2022, **Telstra** signed a PPA with part-owner Ark Energy for 350GWh per annum, sufficient to supply ~ 25% of the telecommunication giant's entire electricity demand.[150]

The following month, **Stanwell** signed a PPA from the majority owner Acciona for 150MW for 15-years from 2025.[151] Acciona signed its foundational PPA with **CleanCo** for 400MW, scheduled to also commence in 2025. Together, the three long-term PPAs have provided a guaranteed revenue stream for Australia's largest wind farm under construction.

In addition to its 400MW PPA, **CleanCo** had also announced the development of the adjoining 103MW Karara wind farm. Combined, the wind precinct would have generated sufficient energy to power 700,000 homes across QLD. The Karara wind farm is part of CleanCo's commitment to bringing 1,400MW of new renewables into the market by 2025.[152]

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[144] Renew Economy, Turning Point: First Big Solar Farm Opened in Heart of Coal-Fired Shire, 27 June 2023
[145] CS Energy, Moura Solar Farm to Power over 40,000 Australian Homes with Renewable Energy
[146] OpenNEM, Moura Solar Farm
[147] Acciona, Aldoga Solar Farm
[148] Stanwell, Power Supply Deal with Aldoga Solar Farm to Drive QLD Hydrogen Industry, 25 October 2023
[149] Acciona, MacIntyre Wind Farm
[150] Renew Economy, Telstra Underwrites Australia's Biggest Wind Farm in PPA with Ark Energy, 4 October 2022
[151] Acciona, Acciona Signs PPA to Supply Renewable Energy to Stanwell, 8 November 2022
[152] QLD Government, Over One Million Solar Panels Powering Australia's Largest Solar Farm, 5 April 2023

However, in FY23, CleanCo made the decision to pause the development of its 103MW Karara component, citing significant delays to the connection process (not by the transmission system currently being built by Powerlink) and subsequent cost increases.[153]

CleanCo received an additional $500m from the state government as a down payment to develop 2.3GW of new large-scale wind and solar capacity, primarily across the Central Queensland REZ.[154] The $250m in allocated funding for Karara has now been repurposed towards other renewable energy developments across Queensland.

The development of the majority 923MW component remains on track to be completed by 2025.

Clarke Creek

Clarke Creek is a multi-stage, world-scale wind precinct currently under construction in Central Queensland, 150km northwest of Rockhampton. Clarke Creek is currently being built by Dr Andrew Forrest's **Squadron Energy**, having acquired the project from Goldwind in March 2022.

The first-stage of Clarke Creek is a 450MW wind farm, powered by 100 4.5MW turbines supplied by China's Goldwind, the world's leading wind turbine manufacturer.[155]

Stage 1 began construction in July 2022, and after some delays with the takeover of operations from Windlab (of which Dr Andrew Forrest is a 75% owner), construction was restarted in June 2023. Squadron installed the first turbine in October 2023.[156] Squadron expects to have 6 of the 100 turbines fully erected by December 2023.[157]

In August 2020, **Stanwell** announced a 348MW PPA for the 450MW first-stage of Clarke Creek wind farm.[158] The PPA represents ~ 75% of Stage 1's output over 15-years.[159]

Clarke Creek Stage 2 is a proposed 564MW wind farm of 94 6MW turbines, capable of generating enough power to supply 350,000 homes in QLD.[160] Across 76,300 ha over eight private landholdings, the combined $3bn Clarke Creek wind precinct could power ~ 40% of Queensland's households.[161]

Forrest's Squadron Energy acquired **CWP Renewables** in December 2022 for $4bn, adding significant expertise to the Australian energy developer, as well as 2.4GW of established capacity and a 20GW development pipeline.[162] January 2024 saw Squadron Energy commit to financing and developing 14GW of new renewable projects across Australia, with a $2.75bn supply agreement with GE Vernova for wind turbines.[163] Squadron confirmed the remaining 6GW of CWP's pipeline will follow.

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[153] CleanCo, CleanCo Annual Report FY23, 31 October 2023
[154] Renew Economy, CleanCo Gets Extra $500m to Develop 2.3GW of New Wind and Solar, 6 June 2023
[155] Squadron Energy, Clarke Creek Wind Farm Stage 1
[156] Squadron, First Turbine Installed at Clarke Creek Wind Farm, 5 October 2023
[157] Squadron, Clarke Creek Wind Farm Project Update November 2023, 16 November 2023
[158] Stanwell, Future Energy Solutions: Wind Energy – Clarke Creek Wind Farm
[159] Renew Economy, First Turbine Goes Up at Forrest-backed Clarke Creek Wind Farm, 28 September 2023
[160] Squadron, Clarke Creek Wind Farm Stage 2
[161] Squadron, Construction Begins on Australia's Largest Renewable Energy Project, 6 July 2022
[162] AFR, Andrew Forrest is Australia's Biggest Renewables Player, 7 December 2022
[163] Squadron, Squadron Starts Work on Largest NSW Wind Farm and Commits to 14GW Renewable Energy Pipeline, 11 January 2024

Wambo Wind Farm

Wambo is a multi-stage wind project under development by a 50:50 JV between **Cubico Sustainable Investments**, a global investor in renewable energy, and state-owned generator **Stanwell Co**.[164] Stage 1 consists of 42 6MW turbines, totalling 252MW, located in the Western Downs region of Queensland. Stanwell will own 50% of the electricity generation, with Cubico's share set to be locked down with a long-term PPA.

The wind farm will be connected by a new double circuit 275kV transmission line between a proposed Diamondy substation at the wind farm, and the existing Halys substation.[165]

Construction began in June 2023, with Stanwell's capital injection backed by a $192.5m allocation from the QREHJF, representing 50% of the total $385m capex.[166]

Tarong West Wind Farm

In September 2022, the QLD Government announced a funding injection of $776m into **Stanwell Co**. for the development of the 500MW Tarong West wind farm.[167] The funding would be provided from the $2bn Queensland REHJF. A final investment decision (FID) is expected in 2024, with commercial operations beginning from 2026.

Mt Hopeful Wind Farm

Mt Hopeful is a 350MW wind farm proposed by Neoen, 70km west of Gladstone. The proposed site is within the Central REZ, in close proximity to Stanwell coal power station. The wind farm would comprise of 60 turbines.

Neoen has not begun construction, however Stanwell signed a 15-year PPA with Neoen for 215MW offtake from Mt Hopeful, representing ~ 60% of the planned capacity of the project. Stanwell and Neoen have also agreed to explore further partnership opportunities in Queensland.[168]

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[164] Wambo Wind Farm, Wambo – Clean Renewable Energy
[165] Powerlink, Wambo Wind Farm Connection Project
[166] QLD Government, Wambo Wind Farm Joins Queensland's Race to Renewables, 8 June 2023
[167] QLD Government, Queenslanders to Take More Ownership Over Clean Energy Target, 26 September 2022
[168] Stanwell, Future Energy Solutions: Wind Energy – Mt Hopeful Wind Farm

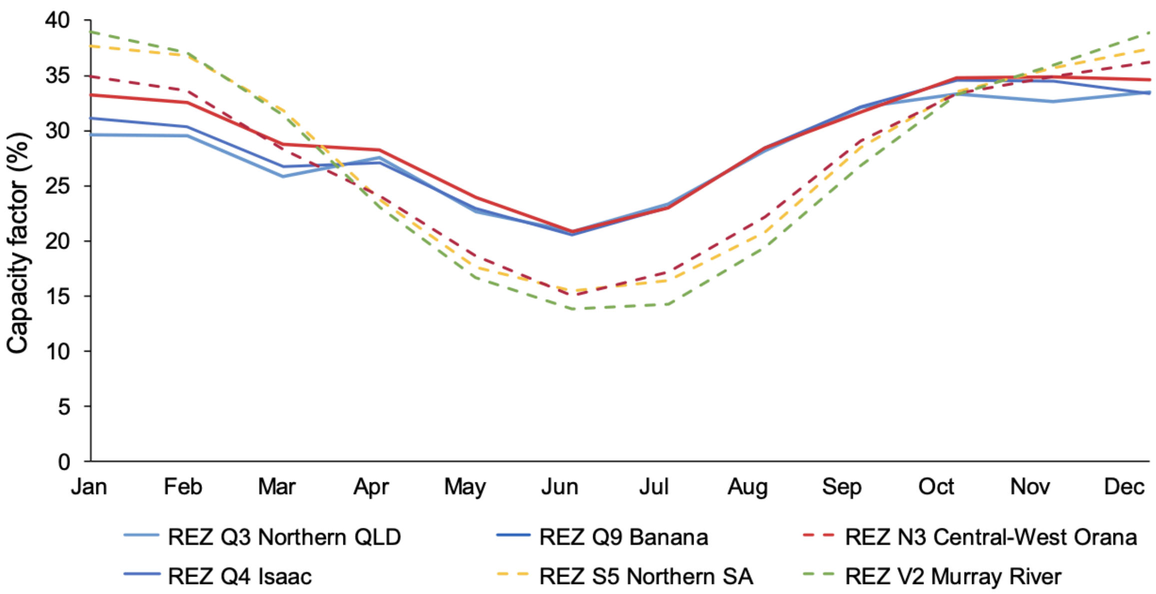
Section 7. Grid Firming Solutions

Grid firming solutions are required in a decarbonised grid to shift renewable energy generation to evening peak demand and ensure sufficient energy is dispatchable during lower solar and wind periods. Batteries will play a significant and growing role in grid firming as they can be deployed at speed and scale, and are seeing massive technology improvements and cost deflation. BESS also complements the ever-growing distributed solar network to bolster distributed energy systems and reduce system load. Volume-weighted (on end-use) battery cell prices have experienced significant deflation over time, dropping 90% in the last 10-years. With 250MW/450MWh currently deployed, there is an additional 3,250MW/7,100MWh of additional capacity either under construction or in advanced stages towards FID.

Australia, and especially Queensland, has historically benefited from the simplicity of dispatchable generation to power its energy demands. As coal-powered power plants and gas peaking plants generation can be scheduled, fossil fuels could provide energy on command to ensure supply met demand to maintain grid stability. Of late, this has been undermined by increasing cost of fossil fuel commodities, aging thermal power plants and global finance's flight from fossil fuels in light of the climate change science, along with the inevitability of pricing of carbon emissions and similar policy headwinds.

Due to the variable nature of wind and solar generation, a decarbonised energy system requires grid-firming technology to ensure demand can be met during times of no wind after the sun has predictably set each day. Firming solutions are required to meet both intra-day supply gaps to meet peak demand, as well as longer duration storage to cover extended periods of lower solar and wind generation i.e. over winter or in droughts.

Figure 7.1: Monthly Solar Capacity Factors – QLD vs Other NEM States:



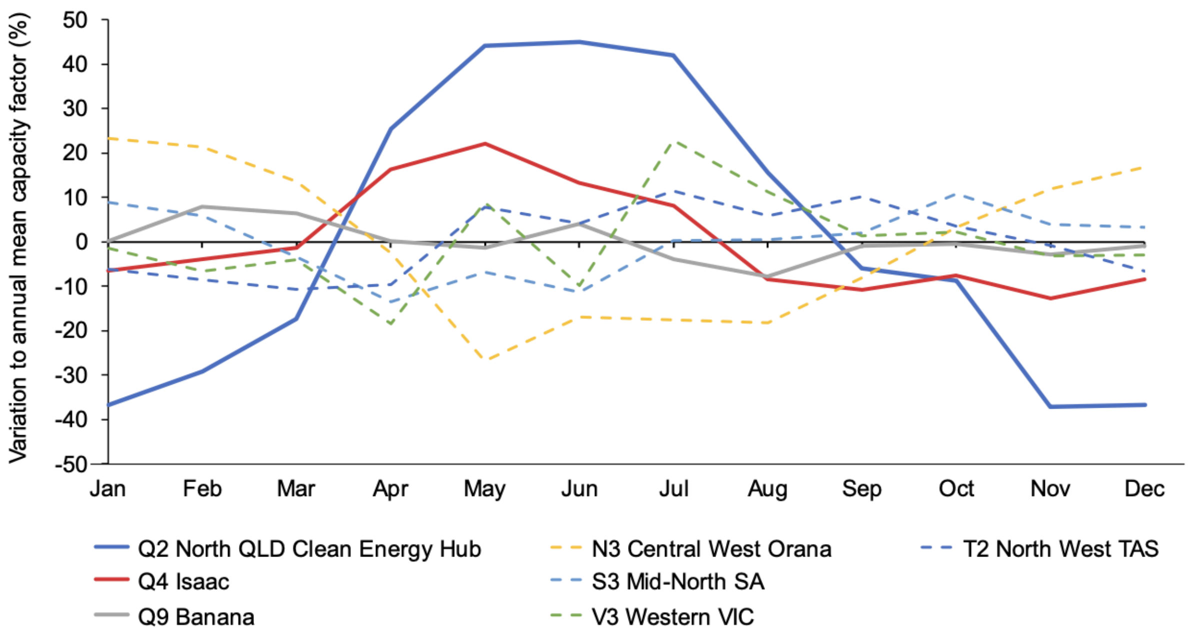
Source: AEMO 2022
Note: Extracted from Griffith University QLD Green Ammonia Report 2023 [169]

[169] Griffith University, Queensland Green Ammonia Value Chain: Decarbonising hard-to-abate Sectors and the NEM, November 2023

The QEJP refers to the extended periods as *renewable drought*, or *dunkelflaute*, meaning dark doldrums or dark wind lull to describe periods of low wind and solar generation. Queensland, however, is blessed with abundant solar and wind resources year-round. Across NSW, Victoria and South Australia, average solar capacity factor fluctuates from a peak of 35-40% in summer, to 15-20% over winter. Whereas QLD's volatility is far less, fluctuating from 30-35% in winter, to 20-25% over winter - Figure 7.1.

The reduced level of fluctuation in QLD's solar capacity factors creates an even more economical case for the deployment of renewable generation and storage further than its deflationary nature, by reducing the long-duration storage requirements over winter, and reducing the 'energy spill' over summer. Additionally, QLD's wind resources counteract the reduction in energy generation from solar over winter, demonstrating a far greater peak over winter than the renewable energy zones in Tasmania, South Australia, NSW and Victoria - Figure 7.2.

Figure 7.2: Monthly Wind Capacity Factors Variation Indexed to Annual Mean – QLD vs Other NEM States:



Source: AEMO 2022
Note: Extracted from Griffith University QLD Green Ammonia Report 2023 [170]

Grid firming solutions will be required in a decarbonised grid to shift renewable energy generation to evening peak demand and ensure sufficient energy is dispatchable during lower solar and wind periods. Thus, firming technologies must cover a range of short-duration / intra-day supply deficits from generation, as well as long-duration storage. Grid firming can be characterised into:

- **Intra-day storage** – batteries designed to absorb excess solar energy from the grid, store it, then discharge later in the day to meet demand.

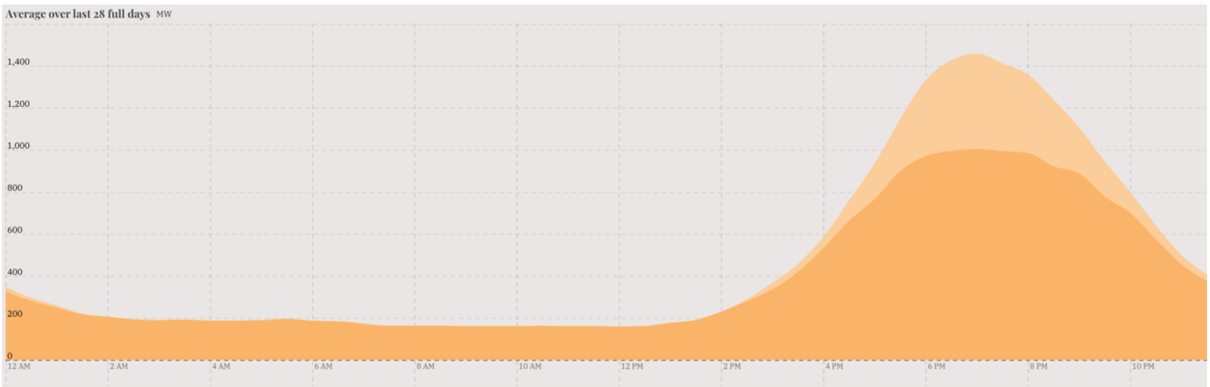
[170] Griffith University, Queensland Green Ammonia Value Chain: Decarbonising hard-to-abate Sectors and the NEM, November 2023

- **Short duration energy storage** (SDES) – grid-connected energy storage with duration less than 4 hours. The value of SDES is capacity, fast ramping and FCAS, as opposed to its energy value.
- **Medium duration energy storage** (MDES) – duration between 4-12 hours. As well as providing similar benefits to SDES, MDES also provides intra-day energy shifting capabilities, driven by the daily shape of energy consumption by consumers, and the diurnal solar generation pattern.
- **Long duration energy storage** (LDES) – duration beyond 24 hours. In addition to the benefits of MDES, LDES is able to maintain short term periods of low renewable generation and contribute to managing renewable energy droughts.
- **Pumped hydro storage** (PHS) – Is an energy storage technology that provides inertia and other services that support power system security and are dispatchable plants i.e. can be switched on when required.

To meet the majority of Queensland's grid firming requirements, given its reduced volatility in solar capacity over the year, as well as having greater coverage of wind generation during winter, we see **batteries as one of the key choices** able to now be deployed at speed and scale, as well as to attach to the ever-growing distributed solar network to bolster distributed energy systems and reduce system load.

Alongside a ramp-up of baseload generation of coal during peak demand, the majority of Queensland's current additional peaking energy is sourced from **Combined-Cycle Gas Turbines** (CCGT), averaging near 1,000MW of power during peak demand (7PM), with an additional ~ 450MW from **Open-Cycle Gas Turbines** (OCGT) - Figure 7.3.

<u>Figure 7.3: Fast Flexible Fossil Gas Peaking in Queensland Grid December 2023</u>

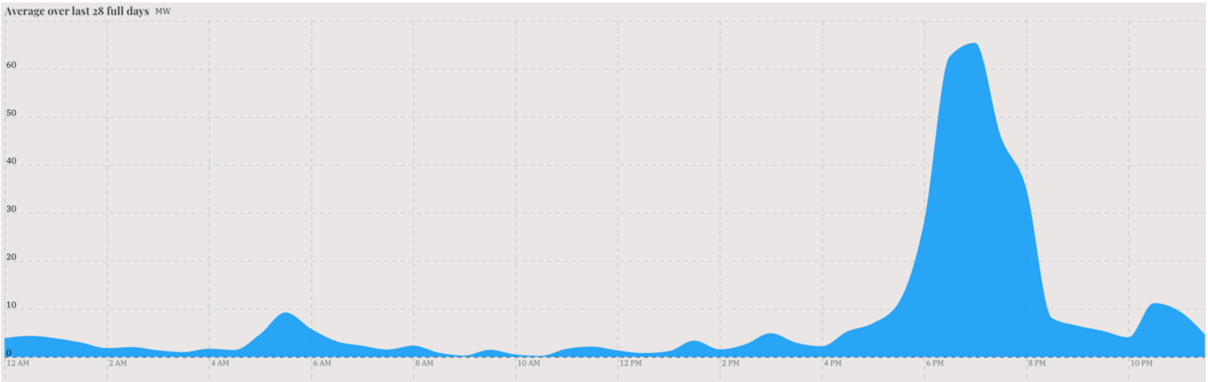


Source: OpenNEM

As Queensland transitions to a decarbonised economy, zero-emissions generation and grid firming solutions must replace the outdated historic concept of baseload fossil fuel generation during peak and off-peak demand, as well as progressively replacing gas peakers. Currently, the majority of Queensland's battery discharging is during peak demand, followed by charging during periods of high solar and wind generation.

Utility-scale and distributed BESS are a key part of the future of Queensland's energy system. Through the QEJP, Queensland has placed a greater capital focus on PHS to power the state. However, to-date, battery technology has proven to be a more economical solution to grid firming, with falling battery prices as a product of fast-growing global battery manufacturing capacity. In addition to the simplicity of associated home battery systems with distributed PV to reduce the pressure on Queensland's transmission and distribution network, and provide real energy savings to households, batteries in EVs are expected to also provide significant grid enhancements as V2G technologies become mainstream by the end of this decade. The growth of both utility-scale and btm BESS storage will reduce the demand for gas peakers, as shown in the similar power dynamics of battery discharging to gas in Figure 7.4

Figure 7.4: Battery Discharging in Queensland Grid December 2023



Source: OpenNEM

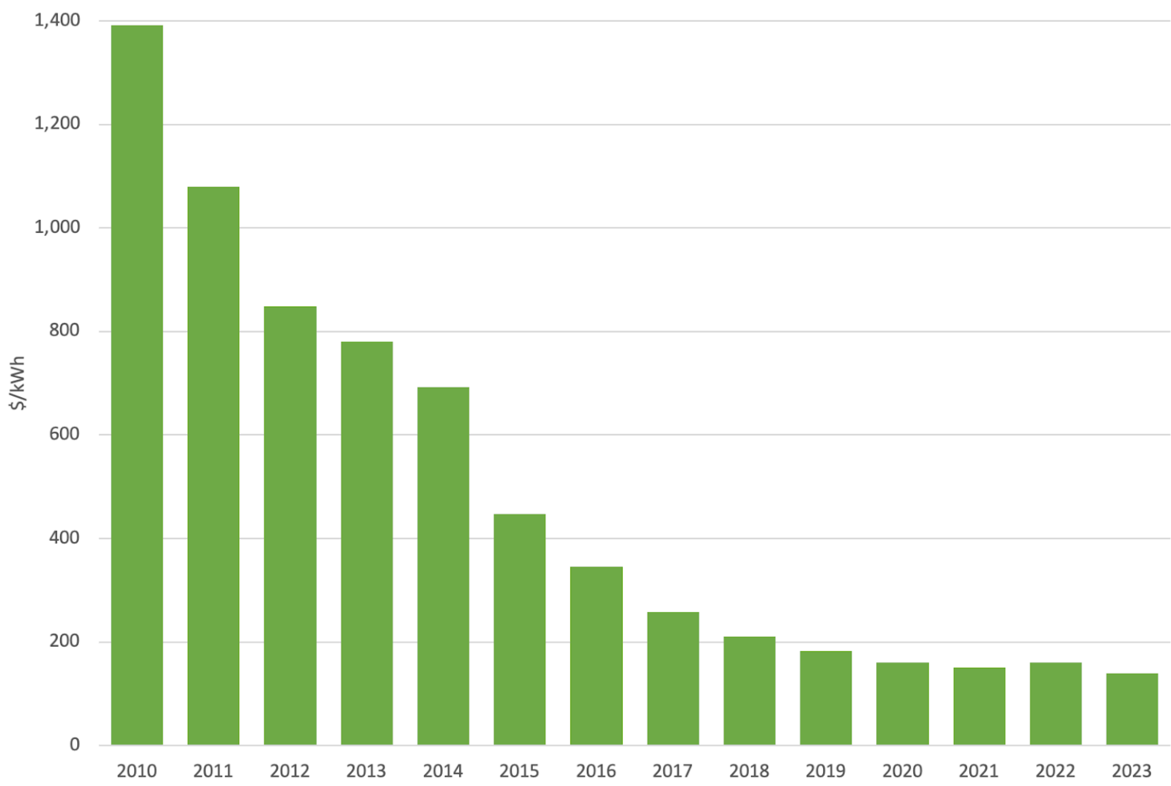
Section 7.1. Battery Energy Storage

Technology costs are reduced by manufacturers 'learning-by-doing', in which the unit costs diminish as cumulative capacity of a technology grows, with more effective production methods and higher efficiencies across all scopes of research, design and distribution, and scaling up manufacturing capacity. Battery technology is no different. Volume-weighted (on end-use) battery cell prices have experienced significant deflation over time, dropping 90% in the last 10-years - FIgure 7.5.

Queensland currently has a total of 250MW/450MWh of large-scale BESS operating across 2 large-scale sites, Wandoan South and Bouldercombe, with Chinchilla set to be operational by early 2024. As the learning curve for utility-scale firming matures, alongside deflating battery capital costs and our forecast for a return to deflationary trends in LCOE for renewables, Queensland will experience a significant uptick in battery deployment.

The QLD Government must work with the Federal government to leverage the four-fold expansion of the capacity investment scheme (CIS) to best realise this opportunity, deploying patient public capital and public contract underwrites at speed and scale to crowd in private developers as well as global battery developers to recognise the true scope of the state's, and by extension the nation's, battery adoption and manufacturing opportunity.

Figure 7.5: Lithium-ion Battery Price Deflation



Source: BloombergNEF [171]
Note: Values are averages across passenger EVs, commercial vehicles, buses, two- and three-wheelers and stationary storage. Includes cell and pack.

[171] Bloomberg, Battery Prices are Falling Again as Raw Material Costs Drop, 27 November 2023

Wandoan South

Wandoan is Queensland's first large-scale BESS, located in the Darling Downs region. Wandoan is a $120m **100MW/150MWh** system developed by **Vena Energy**.[172]

In August 2022, Wandoan South BESS commenced full operations. Following successful commissioning, full operational dispatch rights were formally transferred to AGL on a fixed long-term contract for 15-years.[173]

Vena Energy constructed the 125MW Wandoan South Solar project after the BESS became operational. This marked the first instance of a large-scale solar farm to be added to an existing big battery facility in Australia.[174] Wandoan South had first output in May 2023, and has steadily ramped up over 2023, producing over 23GWh in December 2023.[175]

Bouldercombe

The **50MW/100MWh** Bouldercombe battery project is **Genex Power**'s first large-scale BESS project in Australia. The BESS is comprised of 40 Tesla Megapack units. Located next to an existing SuperGrid substation, and within the local Gracemere region, one of the top 50 solar postcodes in QLD, means Bouldercombe is soaking up cheap renewable energy supplied from distributed rooftop solar PV. This is discharging back to the community, lowering the region's energy bills and reducing reliance on baseload fossil fuel generation.[176]

The Bouldercombe battery operates on an arbitrage/FCAS revenue model, with the system able to bid into all eight existing FCAS markets, and able to participate in future markets for inertia and fast frequency responses currently under development.[177]

Chinchilla

The **100MW/200MWh** Chinchilla battery is state-owned energy firm **CS Energy**'s first grid-scale battery, located adjacent to its Kogan Creek coal plant near Chinchilla. The $150m big battery consists of 90 Tesla Megapack units, and is part of the QLD Government's response to safeguard Queenslanders from critical failure points like Callide C coal plant.[178]

Chinchilla was connected to the grid in November 2023, with commissioning following to be operational by early 2024.[179] The BESS is the first instalment of CS Energy's planned Kogan Creek Clean Energy Hub.[180]

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[172] Vena Energy, Wandoan South BESS, 24 August 2022
[173] AGL, Queensland's Largest Fully Operational Commercial Scale Battery, 24 August 2022
[174] Renew Economy, First Major Solar Farm to be Added to a Big Battery Starts Operations in Australia, 29 May 2023
[175] OpenNEM, Wandoan Solar Farm
[176] QLD Government, Bouldercombe's Big Bessie Goes Live to Battle Bills for Rocky Residents, 17 July 2023
[177] Genex Power, 50MW/100MWh Bouldercombe Battery Project
[178] Renew Economy, Chinchilla Big Battery Takes Shape Next to Country's Biggest Coal Unit, 19 April 2023
[179] Renew Economy, Chinchilla Big Battery Connects to the Grid, 23 November 2023
[180] QLD Government, Clean Energy Hub Charged Up by Tesla Battery, 19 April 2023

Section 7.1.2. New Battery Storage

Queensland has a fast-growing pipeline of new large-scale battery investments. Beyond the 250MW/450MWh currently deployed, there is an additional 3,250MW/7,100MWh of additional capacity either under construction or in advanced stages towards FID, namely the grid-forming batteries including Neoen's Western Downs and Tag Energy's Mount Fox, both of which have received ARENA funding to assist in grid stability and system inertia.[181]

It is also important to applaud the QLD Government's initiative in transforming its state-owned energy portfolio into renewable energy generation and storage solutions. Between Stanwell, CS Energy and CleanCo, there is a significant investment channel into utility-scale batteries under development at retiring fossil fuel plants.

In addition, AEMO's Generation Information dataset shows a significant pipeline for new investment into BESS. Naming all batteries listed above in advanced stages, AEMO's October publication contains **17,448MW** of new QLD grid-scale battery proposals. Connection requests only require the power of new projects (MW), but not capacity (MWh). However, given that current projects in the advanced pipeline are primarily 2-hr minimum duration batteries, AEMO's dataset shows a conservative **34,896MWh** of potential energy storage - Figure 7.6.[182]

Figure 7.6: QLD Big Battery Projects

Project	Owner	Completed (MW)	Construction (MW)	Announced (MW)	Energy (MWh)
Wandoan South	Vena Energy	100			150
Bouldercombe	Genex Power	50			100
Chinchilla	CS Energy	100			200
Swanbank	CleanCo		250		500
Western Downs	Neoen		270		540
Greenbank	CS Energy			200	400
Blackstone	Octopus			500	1,000
Tarong	Stanwell			300	600
Stanwell	Stanwell			150	300
Mount Fox	Tag Energy			300	600
Bulli Creek	Genex Power			400	1,600
Kaban	Neoen			100	
Yabulu	Ace Energy			200	400
Banana Range	EDF Renewables			50	50
Childers	Elliot Green Power			25	50
Coopers Gap	AGL			100	150
Wambo	RE Partners			50	200
Ulinda Park	Akaysha Energy			150	300
Brendale	Akaysha Energy			205	410
		250	**520**	**2,730**	
				3,500	**7,550**

Source: Renew Economy Big Battery Map of Australia, CEF Calculations

There are currently two major battery projects supported by ARENA that will be equipped with **grid-forming inverters**. Simply, most grid connected batteries are *grid following*, meaning they are dependent on the grid to provide a stable voltage and frequency. This allows them to be simpler and cheaper, as well as achieving faster response times than grid forming inverters. However, grid forming inverters work independently, or in orchestration

[181] Renew Economy, Big Battery Storage Map of Australia
[182] AEMO, Generation Information October 2023, 2 November 2023

with other storage and generating assets, to regulate grid voltage and frequencies to restore power during blackouts or sudden variations in the balance of load and supply.

The ability for VRE generators and dispatchable storage providers to assist in forming the electricity grid is a critical hurdle to reaching 100% renewables. Without grid-forming inverters in batteries, synchronous condensers as well as PHS, we are wholly reliant on the maintenance and propagation of ageing fossil-fuel power plants. We need to straddle the transition from a thermal powered grid of old to a renewable energy and BESS powered grid of the future (but we'll leave that to AEMO and engineers to manage this cross-over).

Currently, grid stability is maintained by synchronous generators, like thermal coal plants, with spinning turbines that maintain system inertia. Whilst wind, solar and batteries do not provide inertia, they can be configured to emulate the inertial response of spinning machines, providing the same stabilising services with 'virtual' inertia.[183] Climate Energy Finance is a finance-based think tank, and does not profess to provide engineering or technical explanations on energy grids. However, CEF recognises the importance of maintaining voltage and frequencies in our energy system to provide reliable and low-cost energy to households until our system can make the technology leap.[184]

The QEJP has a dedicated roadmap to transition its fossil-fuel generation to synchronous condensers over time to assist in maintaining grid stability, by importing a low volume of power to spin existing turbines without generation from burning coal. However, given the ageing nature of thermal-based generators, we must consider how these necessary roles can transition to new zero-emission technologies.

ARENA announced a $176m funding package to support the development of 8 grid-forming utility-scale BESS across Australia to provide essential system stability services that will eventually replace the need for synchronous generation.[185] CEF applauds the Federal Government's initiative to invest in the earlier stages of new future-facing technology learning curves, thus de-risking future investment and innovation from world-leading inverter manufacturers, and reducing the commercial and regulatory barriers to nation-wide deployment.

For Queensland, 2 projects are a part of the initiative, including Neoen's Western Downs Green Power Hub, and Tag Energy's Mount Fox.

Western Downs Green Power Hub

Queensland's largest operational solar farm, Western Downs, will be equipped with a **270MW/540MWh** grid-scale battery, transferring variable solar energy into dispatchable electricity on-site. On 25 July 2023, owner **Neoen** announced a 35% expansion of its Western Downs Battery, scaling to 270MW/540MWh.[186]

Powerlink will construct a new dedicated high-voltage line to the existing Western Downs substation to deliver the range of frequency services and network services of what will be Queensland's first grid-forming big BESS, to be operational during FY25.[187]

[183] IEEFA Australia, Australia's Opportunity to Plan Ahead for a Secure Zero-Emissions Electricity Grid, 18 March 2021

[184] IEEFA Australia, Are we ready for a power grid without coal?, 22 March 2021

[185] ARENA, ARENA Backs Eight Grid-Scale Batteries worth $2.7bn, 17 December 2023

[186] Neoen, Neoen Expands Size of Western Downs Battery in Queensland, 26 July 2023

[187] PV Magazine, Neoen Boosts Western Downs Battery Capacity to 540MWh, 26 July 2023

Mount Fox

The **300MW/600MWh** BESS is being developed by global clean energy firm **Tag Energy**. Supported by ARENA, Tag has accelerated its timeline for the Mount Fox BESS, which will be installed adjacent to the planned 400MW Mount Fox wind farm in North Queensland.

Northern QLD represents one the weakest parts of the current NEM grid, with majority of current baseload generation supplied in Central and Southern regions. However, with an influx of new variable generation from wind and solar set to come online in Northern Queensland REZs, grid-forming assets are critical infrastructure to supply the whole of the state with reliable electricity.[188]

Queensland Government

Through various state-owned energy generators, the Queensland Government is investing heavily into deploying large-scale batteries to provide clean dispatchable electricity.

CS Energy is developing the **200MW/400MWh Greenbank** battery, located within the Logan City Council area (South of Brisbane). The $300m battery, consisting of 108 Tesla 2XL Megapacks, will be able to discharge sufficient energy for 2 hours to power 66,000 homes during peak demand. Greenbank is expected to be operational by mid-2025.[189]

CleanCo has engaged Yurika to deliver a **250MW/500MWh Swanbank** battery, west of Brisbane City, with construction starting February 2024, commissioning due July 2025. The battery would be developed at the existing Swanbank CCGT generator, which CleanCo plans to eventually convert to a Clean Energy Hub.[190] CleanCo was awarded $330m under the QREHJF for the development of Swanbank.[191]

Stanwell is developing two new battery projects, including the **300MW/600MWh Tarong** battery, and the **150MW/300MWh Stanwell** battery. In November 2023, Stanwell announced construction of the Tarong battery was underway.[192]

Ulinda Park

Akaysha Energy has been acquired by US$10 trillion global funds giant Blackrock to construct a range of BESS across Australia, including the **150MW/300MWh Ulinda Park** BESS, located near the Kogan Creek coal plant, Australia's largest single coal unit.[193]

Ulinda Park is expected to be operational in 2025. Akaysha's involvement in Queensland is shadowed by its 850MW/1.68GWh Waratah Super Battery project in NSW, [194] however is a critical addition of private capital working alongside public capital to deliver the energy transition. Akaysha also plans a **205MW/410MWh** Brendale BESS in Brisbane, to provide ancillary services and FCAS to contribute to QLD's grid stability and security.[195]

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[188] Renew Economy, Tag Energy to Press Go on Big Renewables Hub in North Queensland, 19 December 2022
[189] CS Energy, Greenbank Battery
[190] QLD Government, 250MW Swanbank Battery as SEQ Joins Clean Energy Hub Revolution, 9 March 2023
[191] PV Magazine, QLD's CleanCo Opens EOIs for 1.2GW Clean Energy Hub near Brisbane, 26 September 2023
[192] LinkedIn, Stanwell Corporation Limited, November 2023
[193] Renew Economy, 'Unsung Hero:' New Big Battery near Australia's Biggest Coal Unit Gets Go Ahead, 1 November 2023
[194] PV Magazine, Waratah Super Battery Secures Final Planning Approval, 23 February 2023
[195] Akaysha Energy, Brendale BESS

Blackstone

Octopus Energy is expanding its footprint across Australia rapidly, and has now proposed a **500MW/1,000MWh Blackstone** battery project. Octopus acquired the Blackstone project from Firm Power. With a gigawatt-hour of energy storage, it is the largest battery project proposal in Queensland so far.[196]

Section 7.2. Pumped Hydro Storage

Queensland Hydro

Under the QEJP, the QLD Government has committed to the development of two major new PHS projects, **Pioneer-Burdekin** and **Borumba**. PHS is QLD's solution to long-duration energy storage, to safeguard the state's energy security and reliability during periods of renewable drought. The development of the PHS projects will be done via the newly formed publicly-owned entity, **Queensland Hydro**.

Borumba is a 2GW/48GWh (24-hr) PHS project, located 180km northwest of Brisbane. The total capital cost of Borumba is currently estimated at $14.2bn. This puts Borumba at a capacity capital cost of $7,100/kW, and an energy storage capital cost of $296/kWh.

In June 2023, Queensland Hydro received $6bn in equity funding from the Queensland Government to secure planning and construction of the Borumba PHS project. The remaining capital cost will be sourced from debt facilities.[197] Following this, in November 2023, QLD called for an EOI to begin underground tunnelling for the Borumba PHS project.[198]

Pioneer-Burdekin is a two stage PHS project, with Stage 1 with 2.5GW/60GWh due 2032, and Stage 2 delivered by 2035 with 2.5GW/60GWh, bringing total capacity to 5GW/120GWh (24-hr).[199] In February 2023, the QLD Government released an EOI for a Cost Estimation for the Pioneer-Burdekin PHS project. In Queensland Hydro's December 2023 update, a detailed analytical report of the project is to be expected in mid-2024.[200] The total cost of both QLD Hydro projects is currently expected to reach $30bn.[201]

Kidston

Genex Power is developing the 250MW/2GWh Kidston PHS Project (K2 Hydro) in far-north Queensland, the first PHS project developed by the private sector in Australia.[202] K2 Hydro is expected to be complete in the second half of 2024, andonline in 2025.[203]

The total expected construction cost of K2 Hydro including transmission and connection costs is $777m,[204] funded by a 118m equity contribution from Genex Power, $610m

[196] Renew Economy, Octopus Australia Snaps Up GWh Battery Project in QLD, 4 October 2023
[197] Queensland Hydro, Borumba PHES Project Greenlit with $6 Billion Funding, 13 June 2023
[198] QLD Government, Sunshine Coast Hinterland $14.2bn Borumba Pumped Hydro EOI, 4 November 2023
[199] QLD Government EPW, Queensland SuperGrid Infrastructure Blueprint, September 2022
[200] QLD Hydro, Pioneer-Burdekin Pumped Hydro Project December 2023 Update, 12 December 2023
[201] AFR, QLD to Commit $14bn for Mega Pumped Hydro Project, 12 June 2023
[202] Genex Power, Genex Flagship Project: Kidston Pumped Storage Hydro Project
[203] PV Magazine, Genex Power Moves Forward on 250MW/2GWh Pumped Hydro Project, 16 August 2023
[204] AFR, Green Energy's Holy Grail Takes Shape 220m Underground, 4 August 2023

long-term debt from NAIF, and a $47m non-recoupable ARENA grant.[205] This puts Kidston at a capacity capital cost of $3,108/kW and an energy storage capital cost of $389/kWh.

Kidston is on track to power up in the 2HCY2024, following successful excavation of the main access tunnel for underground works.[206] K2 will be connected to the FNQ region of the QLD SuperGrid via a new 186km 275kV transmission line and two associated switching stations, approx. 270km Northwest of Townsville.[207]

Genex signed a binding energy storage services agreement (ESSA) with EnergyAustralia for the 250MW K2 Hydro project for up to 30-years.[208]

Significant Financial Investments for Taxpayers

The current NSW PHS, owned by the Federal Government's Snowy Hydro, is now expected to cost $12bn, doubling from the previous estimate of $5.9bn.[209] Snowy Hydro 2.0 is a 2.2GW/350GWh 160-hr deep storage project. At the new cost estimate, Snowy will have a capacity capital cost of $5,455/kW and an energy storage capital cost of $34/kWh. Even with the cost blowout of Snowy Hydro 2.0, the NSW project has a significant price advantage over QLD projects in deep energy storage driven by the use of two large existing reservoirs.

Current capital cost estimates for PHS have increased by 32% in 2023-24 for 24-hr duration projects, and 3% for 48-hr duration projects, driven primarily by inflationary factors in power equipment and installation rather than reservoirs according to CSIRO's latest GenCost report.[210] PHS has a wider range of cost uncertainty due to the greater influence of site-specific issues. By comparison, batteries are comparatively modular, with the majority of costs independent of the installation site, and many times faster to build.

However, the transition to 100% renewables is challenging and unproven, meaning we must consider the impact and effectiveness of all clean energy generation and storage solutions in order to achieve net zero. As the NEM phases out traditional fossil fuel generators, rotating inertia capacity will become scarce. Unlike batteries, which are asynchronous technologies (unless they are grid-forming) that rely on external forces to provide system strength, PHS can provide critical system security services like maintaining inertia, operating as synchronous condensers whilst consuming minimal amounts of water.

Whilst grid batteries and coordinated CER storage are likely to provide the majority of installed capacity for storage technologies, PHS and reserve gas peakers can provide deep storage capabilities to safeguard the national grid in extended periods of unexpected low renewable energy generation. AEMO's draft ISP 2024 highlights the majority of energy storage across the NEM will be from NSW's Snowy 2.0, QLD's Borumba, and other deep storage hydro projects, e.g. Kidston PHS - Figure 7.7.

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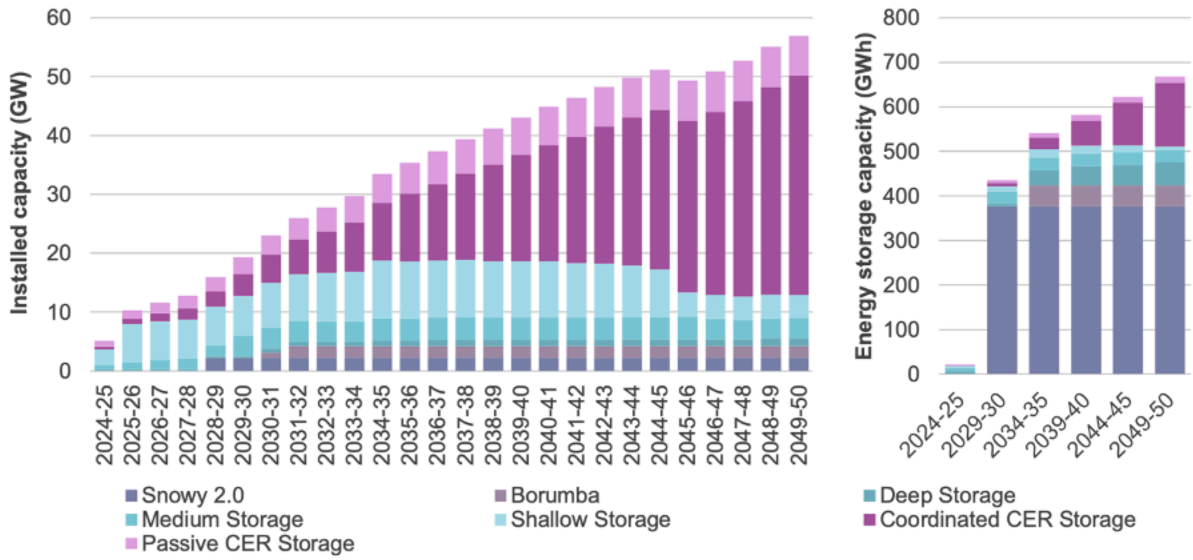
[205] Genex Power, Kidston Pumped Storage Hydro Project Financial Close, August 2021
[206] Renew Economy, Extremely Significant: Genex Hails Kidston PHES Tunnelling Milestone, 3 November 2023
[207] Powerlink, Genex Kidston Connection Project
[208] PV Magazine, Eureka Moment for Kidston Pumped Storage Hydro Project, 30 March 2020
[209] AFR, Snowy Needs $3bn Extra Capital as 2.0 Costs Blowout, 31 August 2023
[210] CSIRO, GenCost 2023-24 Draft, 20 December 2023

Figure 7.7: NEM-wide Storage Installed Capacity and Energy Storage Capacity



Source: Draft ISP 2024 Appendix 2. Generation and Storage Development [211]

Snowy Hydro and Queensland Hydro are publicly-owned PHS entities. CEF recognises that keeping the lights on through the energy transition is of paramount importance for Federal and state governments. As the commercial viability of PHS funded by private capital in Australia declines, Australian-owned energy firms are ensuring the value and security that PHS projects add to the electricity grid are not discounted.

Given the cost blowouts associated with Snowy 2.0, CEF recommends that the development of Stage 2 of Pioneer-Burdekin PHS be evaluated after the construction of QLD's primary PHS project, Borumba. Investment into PHS is a costly, long-term proposition, with typical design life of at least 50-years, with operating life greatly exceeding this in practice.[212] Given the capital intensity of deep storage PHS projects, the evaluation of QLD's energy dynamics and ability for existing PHS and batteries, both btm and utility-scale, to power the state during periods of low renewable output, should be re-evaluated as Borumba is sufficiently progressed to prove if it will avoid the capital cost and timetable blowouts of Snowy 2.0 before determining if Stage 2 of Pioneer-Burdekin will be required during the QEJP timeline.

[211] AEMO, Draft ISP 2024 Appendix 2. Generation and Storage Development, 15 December 2023
[212] Renew Economy, Pumped Hydro: The Power of Gravity and Moving Water, 27 August 2022

Section 8. Emerging Hydrogen Industry Opportunities

Agriculture and natural resources are critical components to QLD's economy, driving employment, investment and GDP growth for decades. However, these industries have become significantly over-exposed to the risks of fossil fuel inflation and environmental degradation. Methane gas used in the production of ammonia, a feedstock for fertilisers and explosives, presents a significant opportunity for decarbonisation and hydrogen supply chains. The decarbonisation of QLD's economy provides an immense opportunity for new green hydrogen industries that will facilitate the phase-out of diesel, gas and oil in ammonia production, mining, and value-added metal and mineral refining.

The Grattan Institute highlights the most promising uses of hydrogen are in the production of ammonia, alumina and iron, using hydrogen efficiently and cost-effectively at scale to support a long-term transformation of industry without excessive subsidisation. Green ammonia presents an immense opportunity for Australia to pivot to producing decarbonised fertilisers and explosives, inputs critical to the agricultural and resource sectors that underpin Australia's economy.[213]

Currently, 95 million tonnes per annum (Mtpa) of hydrogen is produced globally, 43% of which is directed into oil refining, and 33% is used as an input for ammonia production. The world produces 176Mtpa of ammonia, produced predominantly from fossil fuels, with 70% of hydrogen used in ammonia production sourced from methane gas steam reforming, and majority of the difference sourced from coal gasification - Figure 8.1.

Figure 8.1: Green Ammonia Market Opportunity Excluding Energy Use Cases (mtpa NH_3-e)

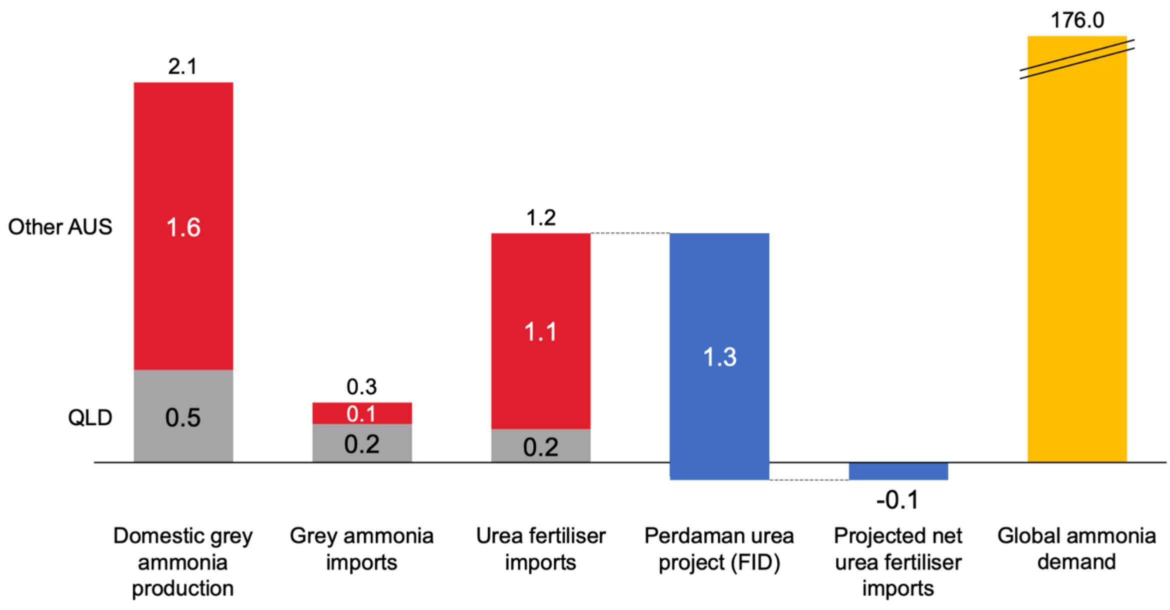


Figure 2: Green ammonia market opportunity excluding energy use cases

Source: (Gladstone Ports Corporation, 2023; Port of Newcastle, 2023; Australian Government - Department of Industry, Science, Energy and Resources, 2021; Australian Trade and Investment Commission, 2023; Clean Energy Finance Corporation & Advisian, 2021; Incitec Pivot, 2023A; Incitec Pivot, 2023B; Incitec Pivot, 2023C; Orica, 2023A; Orica, 2023B).

Note: Extract from Griffith University Green Ammonia Value Chain Study [214]

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[213] Griffith University, QLD Green Ammonia Value Chain, 30 November 2023
[214] Griffith University, QLD Green Ammonia Value Chain, 30 November 2023

The most effective way to maximise the green hydrogen opportunity is to make strategic decisions about its industrial applications that leverage Australia's comparative advantage in renewable energy resources and minerals, and build on existing export industries.[215]

The coupling of Queensland's deployment of utility-scale renewable energy generation with energy-intensive end-use sectors can provide immense benefits to both industries. Emerging green hydrogen and green ammonia projects will create strong demand signals and guarantee revenue streams for developers through long-term PPAs, crowding in further capital in deploying renewable energy generation and storage at scale.

Coupling generation with end-use sectors can provide needed flexibility and reliability to the current energy system, introducing flexible industrial loads with demand response mechanisms, which in turn creates strong pricing signals for other customers to load shift to periods of higher renewable penetration. This in turn, reduces curtailment of low-cost renewable energy, maximising investment yields for developers and green energy asset owners.

To support the development of Queensland's hydrogen industry, the QREHJF expanded by $2bn to $4.5bn. The QREHJF provides funding for publicly-owned energy corporations to increase ownership and strategic investments in commercial renewable energy and hydrogen projects, in addition to supporting infrastructure, in partnership with the private sector. The REHJF is a positive step forward in realising QLD's renewable energy potential, crowding in significant investment from private capital in both end-use sectors and energy generation assets.

Central Queensland Hydrogen Project (CQ-H2)

CQ-H2 is Queensland's largest renewable hydrogen proposal, with a planned phased development of reaching commercial production in 2028, at 200 tonne per day (tpd) with an installed electrolyser capacity of 640MW, ramping up to 800tpd by early 2030s, with a rated electrolyser output proposed of 2GW.

CQ-H2 is being developed by a consortium of domestic publicly-owned energy entities as well as domestic and foreign private capital investors. The consortium includes Stanwell Corporation, Iwatani Corporation, Marubeni Corporation, Kansai Electric Power Company and Keppel Infrastructure. The CQ-H2 project has secured FEED funding from all consortium members, as well as $20m from ARENA, and $15m from the QREHJF.

To power the CQ-H2 project from zero-emissions electricity, the facility would require at least 7GW of associated renewable energy generation capacity.[216] Contracting renewable capacity through long-term PPAs provides a significant opportunity for renewable energy developers to build assets across the Central Queensland REZs.

In October 2023, Stanwell signed a 15-year PPA for 100% of the output generated from the 380MW Aldoga Solar Farm being developed by Acciona.[217] Positioned within the Gladstone State Development Area and in close proximity to the planned hydrogen production facility of CQ-H2. The long-term PPA perfectly highlights the complementary benefits of coupling end-uses with clean energy developers, by underwriting future revenue to accelerate the

[215] Grattan Institute, Hydrogen: Hype, Hope, or Hard Work?, December 2023
[216] CSIRO, Central Queensland Hydrogen Project, 14 September 2023
[217] Stanwell, Power Supply Deal Secured with Aldoga Solar Farm, 25 October 2023

development of existing projects and improve the investment landscape for new projects in the pipeline.

Gibson Island

Fortescue Future Industries has proposed a partnership with Incitec Pivot to decarbonise ammonia production on Gibson Island, using green hydrogen generated from renewable energy. Incitec Pivot currently operates the Gibson Island ammonia plant, producing 300,000tpa,[218] but at the end of 2023 Incitec Pivot closed its associated co-located urea plant, [219] reducing the strategic merit of this location for a green ammonia facility.

The project to transition the plant to green ammonia would involve a new ~500MW hydrogen electrolysis facility, and upgrading the manufacturing facility to produce up to 400,000tpa.[220]

The partnership secured $14m from ARENA to undertake the FEED study, estimated at $38m in total. The FEED study is expected to be complete in March 2024.[221]

Fortescue signed a major 25-year PPA for 337.5MW from Genex Power's Bulli Creek Solar Farm to power the planned 385,000tpa green ammonia retrofit of Incitec's Gibson Island.[222] The supply deal would represent ~20% of the energy demand of the ammonia plant.

The long-term PPA was conditional on Fortescue reaching financial close on Gibson Island by 31 December 2023, and for Genex Power to reach financial close on Bulli Creek Solar by 31 December 2024. On 22nd December 2023, Genex extended the sunset date for Fortescue FID to 28 February 2024, and Bulli Creek to 31 March 2025.[223]

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[218] QLD Government, Gibson Island Study to Build on QLD's Hydrogen Capabilities, 13 June 2023
[219] Grain Central, Gibson Island decision due by year end: IPL, 22 November 2023
[220] Incitec Pivot, Green Conversion at Gibson Island, 20 November 2023
[221] ARENA, Gibson Island Renewable Ammonia Project FEED Study, 7 October 2023
[222] AFR, Fortescue Hunting More Green Energy after Signing 25-year Supply Deal, 9 October 2023
[223] Genex Power, Bulli Creek Solar Project Update on Fortescue Offtake, 22 December 2023