Distributed energy resource forecasts for Energex & Ergon Energy Network

MAY 2023

Part of Energy Queensland

Authors & acknowledgements

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At Blunomy, we believe the best is yet to come. We join the dots between business and finance to develop the strategies, tools, partnerships and transactions which facilitate the systemic shift our planet needs. We are a pioneering team of experienced data, business and transition experts, combining our different backgrounds and skill sets to make change happen.

We develop scalable tools to help energy networks operationalise the transition to a more decarbonised and decentralised grid. This includes supporting forecasting activities relating to increased impact of distributed energy resources on their network.

We have been operating since 2007, previously trading as Enea Consulting.

Part of Energy Queensland

Energex and Ergon Energy Network are Energy Queensland's distribution brands, providing electricity and maintaining the network across Queensland. Energy Queensland is the group of electricity distribution, retail and energy services businesses 100% owned by the State of Queensland.

Energex builds, operates and maintains the electricity distribution network in the growing region of Southeast Queensland, which includes the major urban areas of Brisbane, Gold Coast, Sunshine Coast, Logan, Ipswich, Redlands and Moreton Bay. Today, Energex provides distribution services to more than 1.5 million domestic and business connections, delivering electricity to a population base of around 3.5 million people.

Ergon Energy Network builds, operates and maintains the electricity distribution network for regional Queensland. Ergon Energy Network supplies electricity to 746,000 customers across a vast operating area of over one million square kilometres — around 97% of the state of Queensland.

Executive Summary

DISTRIBUTED ENERGY RESOURCES

Energy systems globally are transitioning to a renewable future, and the Australian electricity system is changing as more people install distributed energy resources, or DER. This includes technologies such as rooftop solar photovoltaics (PV), behind-the-meter battery energy storage systems (BESS), and electric vehicles. In Queensland, nearly 33% of customers connected to Energex and Ergon Energy Network already have a rooftop solar PV system installed, with the use of solar and other DER expected to continue rising.

Net zero initiatives such as the Queensland Energy and Jobs Plan and the Queensland Climate Transition Strategy, in the context of the global energy transition, will require an increasing share of renewables to be integrated into the generation mix. This includes large solar farms and grid-scale battery storage, as well as smaller technologies such as DER.

Distributed energy resources are changing the way customers use electricity, with the rise in DER influencing demand and energy growth. The use of DER is also changing the shape of customer load profiles across the day, and throughout the year. These changes are causing a range of challenges on existing distribution networks, which were historically designed to deliver electricity in one direction.

Addressing these challenges requires distribution networks to develop new knowledge and capabilities, changing how they operate local networks to enable the integration of more DER into the electricity system. Planning for DER uptake is therefore increasingly important for electricity distribution networks, in an energy system that is becoming more decentralised and is characterised by rapid technological change.

QUEENSLAND'S ELECTRICITY DISTRIBUTION NETWORKS

Energex and Ergon Energy Network are Energy Queensland's distribution businesses, licensed to operate the electricity distribution networks across Queensland. In this role, Energex and Ergon Energy are responsible for managing and operating the networks to maintain safety, reliability, and power quality for their customers. As part of this responsibility, Energex and Ergon Energy regularly forecast electricity demand, customer numbers and energy — a critical exercise for electricity distribution businesses. With the rising number of DER on the network, forecasting these technologies is an essential input to inform demand forecasting.

THIS REPORT — FORECASTS FOR DER IN QUEENSLAND

Energex and Ergon Energy Network commissioned this report and engaged Blunomy to deliver a 2023 refresh of its independent DER forecast, first developed in 2022. Several enhancements were made to this year's forecasts with respect to both usability (to feed more seamlessly into the demand forecasts) and outcomes to better align with Queensland's net zero initiatives.

The report presents forecasts for the future count and capacity of DER in Queensland, specifically annual solar PV and behind-the-meter battery storage system installations, and electric vehicle numbers.[1] These forecasts cover the residential, small and large business, and large industrial customer categories.

SLOW, MEDIUM AND FAST UPTAKE SCENARIOS

The DER uptake forecasts are underpinned by a consumer technology adoption curve approach. Each forecast reflects a slow, medium, and fast uptake scenario, defined in consultation with Energex and Ergon Energy Network. Scenarios are used to capture a range of possible futures amidst high levels of uncertainty in how the different drivers of DER uptake — such as technology costs — might evolve and how customers might respond to these drivers in the longer term.

[1] Solar PV excludes large solar farms. Battery energy storage refers to behind-the-meter installations only, and excludes grid-scale, or utility-scale, battery storage systems. Electric vehicles include both battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs).

These scenarios align with Queensland's net zero commitments, such as the Queensland Energy and Jobs Plan, Queensland Climate Transition Strategy and Net Zero Emission Vehicle Strategy 2022–2032.[2]

This report also presents predicted daily DER load profile simulations for BESS — both behind-the-meter and utility-scale, or merchant, batteries — and electric vehicles. Each load profile represents the charging and discharging of a system or vehicle over the course of a day, based on how the system is used or operated. The simulated profiles cover the different days of the week, months of the year, customer categories, technology types, and network electricity tariff categories.

[2] Queensland Government, "Queensland's Zero Emission Vehicle Strategy 2022–2032," March 2022. [Online]. Available: https://www.publications.qld.gov.au/dataset/zeroemissisonvehiclestrategy/resource/cc180075-23bb-499f-8ac2-d1704973feca

KEY RESULTS FROM THE DER FORECASTS

DER uptake in the Energex and Ergon Energy networks is expected to continue rising in the coming years, in line with recent trends exhibited across both networks.

Solar PV rates to rise then slow, and behind-the-meter battery storage to continue growing

In all three scenarios shown in this report, the rate of solar PV is forecast to remain strong in the near term but will likely slow down from 2030 onwards. Behind-the-meter battery storage uptake is expected to continue to slowly grow, with faster growth in the 2030s.

The share of customers with a solar PV system installed is forecast to rise from around 33% at the end 2022 to over 70% by the end of 2036, in the medium uptake scenario. Of these customers with a solar PV system installed, it is forecast that over four per cent will also have a behind-the-meter battery installed by 2036.

Electric vehicle uptake to rise considerably

The uptake of electric vehicles is forecast to rise considerably from 2030 onwards in the medium scenario. The medium scenario is in line with the Queensland Government's target for 50% of sales to be zero emission by 2030 and 100% to be zero emission by 2036, as outlined in Queensland's Net Zero Emission Vehicle Strategy 2022–2032. Electric vehicles are forecast to represent close to 34% of the passenger vehicle fleet by 2036, compared to 0.5% today.

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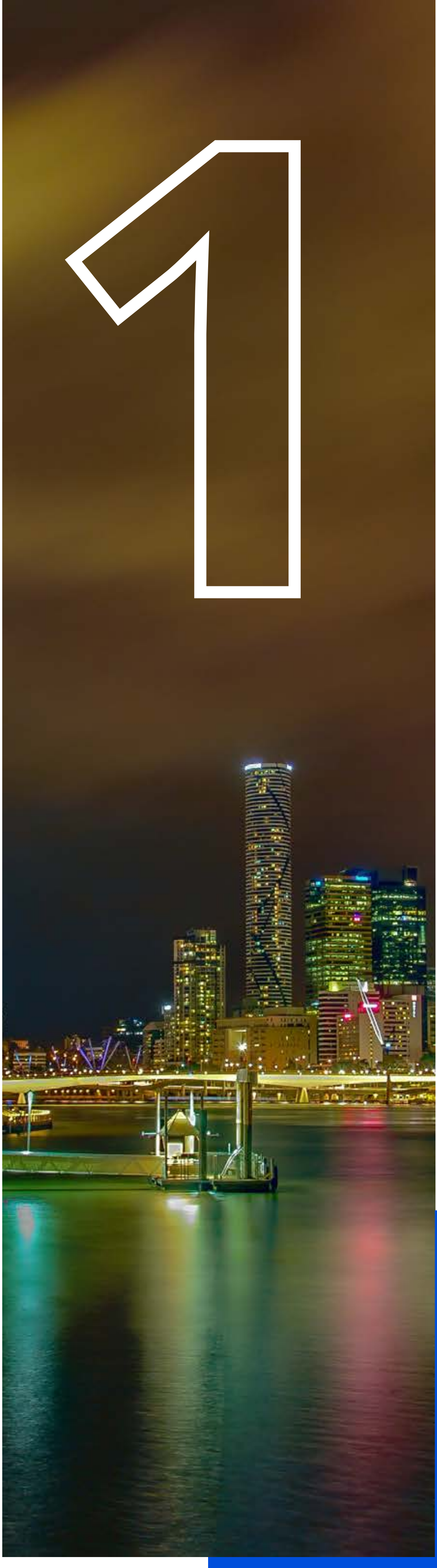


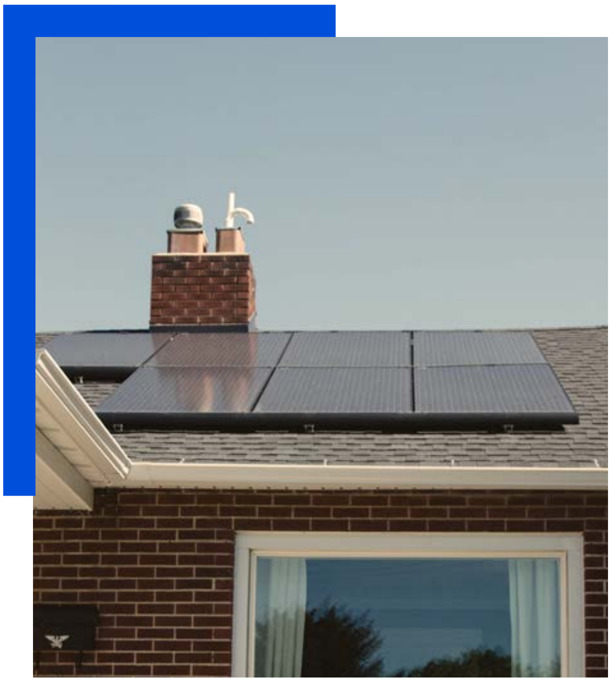
Introduction

THIS CHAPTER

1.1 Energy market context

Energy systems globally are transitioning to a renewable future, and the Australian electricity system is changing as more people install distributed energy resources, or DER. DER are small-scale renewable energy units or systems that generate or store electricity, usually located at homes and businesses. These customer assets include rooftop solar photovoltaics (PV), behind-the-meter BESS, and electric vehicles.

Currently, there are close to 3.4 million rooftop solar PV systems installed on Australian homes and small businesses [1]. In Queensland, there are over 765 thousand solar PV systems installed, with the share of Energex and Ergon Energy Network customers with solar PV systems at nearly 33% at the end of 2022. The share of these customers that also had a battery energy storage system was 1.7% at the end of 2022. This share is growing, increasing from 1.5% in the prior year. The use of other DER, such as electric vehicles, is growing as well.



1.2 Queensland net zero commitments and plans

The Queensland Government is actively supporting the transition to a renewable energy future, with several strategies already in place. These strategies outline pathways to meet decarbonisation targets and maximise the benefits this transition can unlock.

The state government has made multiple commitments towards a zero net emissions future, as part of its action on climate change [2]. This includes several renewable energy targets — with milestones to power Queensland with 50% renewable energy by 2030, 70% by 2032 and 80% by 2035. This works towards Queensland's overarching target to reach zero net emissions by 2050. Queensland's Net Zero Emission Vehicle Strategy 2022–2032 [3] aims to prepare Queensland for a transition to electric vehicles, in support of the longer-term net zero target. The vehicle strategy sets a target for 50% of new passenger vehicle sales in Queensland to be zero emission by 2030. This target increases to 100% of sales by 2036.

A growing number of business and industrial customers are also setting net zero commitments, alongside state and national targets. Within this context, the progressive shift of many sectors towards electrification is expected to contribute to electricity's growing share of total energy consumption. When combined, the Queensland Government's initiatives as well as consumer initiatives, in the context of the global energy transition, will require an increasing share of renewables to be integrated into the electricity generation mix. This includes both large solar farms and grid-scale battery storage and smaller technologies such as rooftop solar PV, behind-the-meter BESS, and electric vehicles.

1.3 Project context and objectives

Distribution network service providers (DNSPs) are responsible for managing and operating electricity distribution networks to maintain the safety, reliability and quality of their customers' power supply. DNSPs are also an enabler of DER uptake, as they change how they operate local networks to integrate a growing number of DER into the electricity system. In Queensland, this responsibility falls on Energex for Southeast Queensland and Ergon Energy Network — also referred to as Ergon Energy throughout this report — for regional Queensland.[3]

One critical activity for any distribution business is forecasting electricity demand, customer numbers and energy, in support of its network planning activities. As such, Energex and Ergon Energy Network undertake regular forecasting exercises. The results of these planning activities are captured in Energex and Ergon Energy's Distribution Annual Planning Reports and distribution determination processes.

Within this context, planning for DER uptake is increasingly important, in an energy system that is characterised by rapid technological change and continuous growth in the penetration of renewable energy resources.

More specifically, distributed energy resources are changing the way customers use electricity, with the rise in DER having a significant influence on demand and energy growth. The use of DER is also changing the shape of customer load profiles across the day, and throughout the year. These changes in customer load can therefore have an impact on the maximum and minimum demand forecasts.

It is within this broader context that Energex and Ergon Energy Network engaged Blunomy to deliver an independent DER forecast for the Queensland distribution networks for the 2023 to 2036 period. This serves as a refresh of the DER uptake forecast and DER load profiles delivered in 2022, with several enhancements requested by Energex and Ergon Energy Network. The enhancements that have been incorporated serve to enable more efficient internal use of the forecast within Energex and Ergon Energy Network, along with factoring in new trends and policy announcements.

As part of this refresh, Blunomy has delivered — in this report — updated forecasts for annual solar PV and behind-the-meter BESS installations, and electric vehicle numbers.[4] Blunomy has also simulated DER load profiles for behind-the-meter BESS and electric vehicles. These profiles capture a range of customer behaviours. For residential batteries, these profiles consider how battery behaviour may change in the future with an increased proportion of batteries acting as virtual power plants (VPPs). A selection of aggregated results for DER uptake and profiles is presented in section 5.1 and section 5.2 of this report.

1.4 Project approach

A consumer technology adoption curve approach underpins the DER uptake forecasts presented in this report. The forecasts were developed using a range of price and non-price drivers to inform different rates of future technology uptake. The approach for forecasting DER uptake is further detailed in section 4.1.

[3] Energex and Ergon Energy Network are owned by Energy Queensland, which is 100% owned by the State of Queensland.

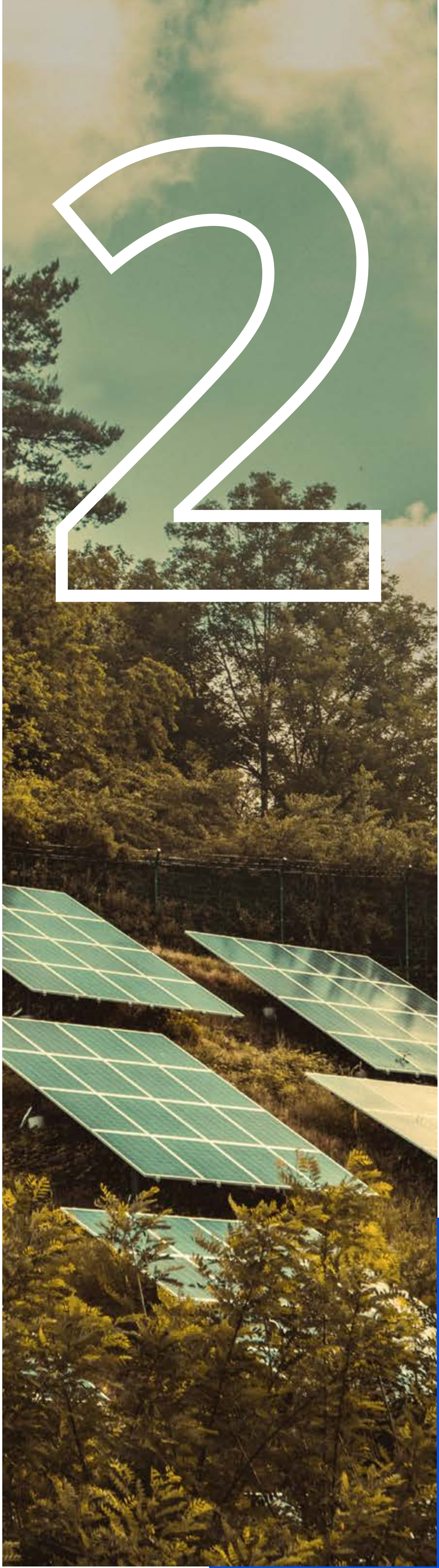
[4] Solar PV excludes large solar farms. Battery energy storage systems refer to behind-the-meter installations only, and excludes grid -scale, or utility -scale, battery storage systems. Electric vehicles include both battery electric vehicles and plug-in hybrid electric vehicles.

The forecasts reflect three scenarios — Slow, Medium, and Fast DER uptake. Using such scenarios ensures that a range of possible outcomes are considered amidst high levels of uncertainty in how the different drivers of DER uptake, such as technology costs, might evolve. Individual forecasts are also provided for each customer category — residential, small and large business, and large industrial. Each forecast is disaggregated at the feeder, legacy region, statistical area level 2 (SA2), zone substation (ZSS), and transmission connection point (TCP) levels for Energex and Ergon Energy Network. This is aligned with Energex and Ergon Energy's electrical demand forecasts, which are undertaken at the system level and calculated for all zone substations and distribution feeders.

Blunomy also developed predicted daily load profiles for BESS and electric vehicles. Each load profile represents the charging and discharging of a system or vehicle over the course of a day, based on how the system is used or operated in response to a customer's behaviour and network price signals. Profiles are simulated for each day over the forecast period, along with each customer category, technology type, and network electricity tariff category (where applicable).

Individual battery operation patterns, as well as electric vehicle drive patterns, are constructed using available historical data, to determine when the systems are or are not in use. Load profiles that represent charging and discharging at different points in time are then constructed, based on the understanding of customer behaviour established through the operation and drive patterns. The approach for developing the DER load profiles is further detailed in section 4.2.

The DER load profile simulations provide Energex and Ergon Energy Network with initial load profiles that can be leveraged as part of future work. For example, the load profiles — which are based on a selection of current network tariffs that are further detailed in section 3 — can inform investigations on the responsiveness of customer behaviour to increasingly dynamic, or near real-time network pricing signals. The load profiles could also inform policies on the management of BESS operation and electric vehicle charging.



Scenario definitions

Scenarios are used in the forecasting exercises presented in this report to capture a range of possible futures. This is because it is highly uncertain how the different drivers of DER uptake might evolve and how consumers might respond to these changing drivers in the longer-term. This is especially true for technology costs. As such, each scenario reflects one possible future, defined by a set of scenario-based inputs and underlying data assumptions.

THIS CHAPTER

2.1 DER uptake

Blunomy's DER uptake forecasts for Energex and Ergon Energy Network, presented in **section 5.1**, reflect three different scenarios — Slow, Medium, and Fast DER uptake. These scenarios were defined in consultation with Energex and Ergon Energy Network and are used in the solar PV, BESS, and electric vehicle forecasts. The input scenarios and assumptions for the Slow, Medium, and Fast scenarios are outlined in **Table 1**.

The scenarios use external inputs that are designed to be generally consistent with a net zero future. The Medium uptake scenario is most closely aligned with reaching a net zero future by 2050. The remaining two scenarios offer a view of a faster and slower pace of transition, compared to the Medium scenario. The pace of DER uptake is determined by each of the different input scenarios used, which cover various rates of change in population, income, and technology development. This in turn leads to variations in the speed of the energy transition, across the different uptake scenarios.

Using scenarios ensures that a range of potential, unknown futures are captured. For example, differences in how technology costs evolve between each of the scenarios will impact the propensity to purchase DER across the forecasting period. The three scenarios outlined in Table 1 are consistent with the scenarios used by Energex and Ergon Energy for internal forecasting activities.

TABLE 1: Energex and Ergon Energy DER uptake scenario definitions

DER uptake scenario	Population	Household Income[5]	Energy Prices	Technology costs	Guiding themes
Slow	Slower and lower growth in population	Slower and lower growth in household income	Faster and higher rises in energy prices	Slower, smaller declines in technology costs	Slower change across drivers, with delayed net zero and dampening of current technological trends
Medium	Central	Central	Central	Central	Net zero targets are met by 2050, in line with existing federal and state policies. Current technological trends continue
Fast	Faster and higher growth in population	Faster and higher growth in household income	Slower and lower rises in energy prices	Faster, larger declines in technology costs	Accelerated decarbonisation, bringing net zero forward. A potential step change in technological progress, exceeding current trends

[5]Household income is applicable for Residential and Small Business customers only.

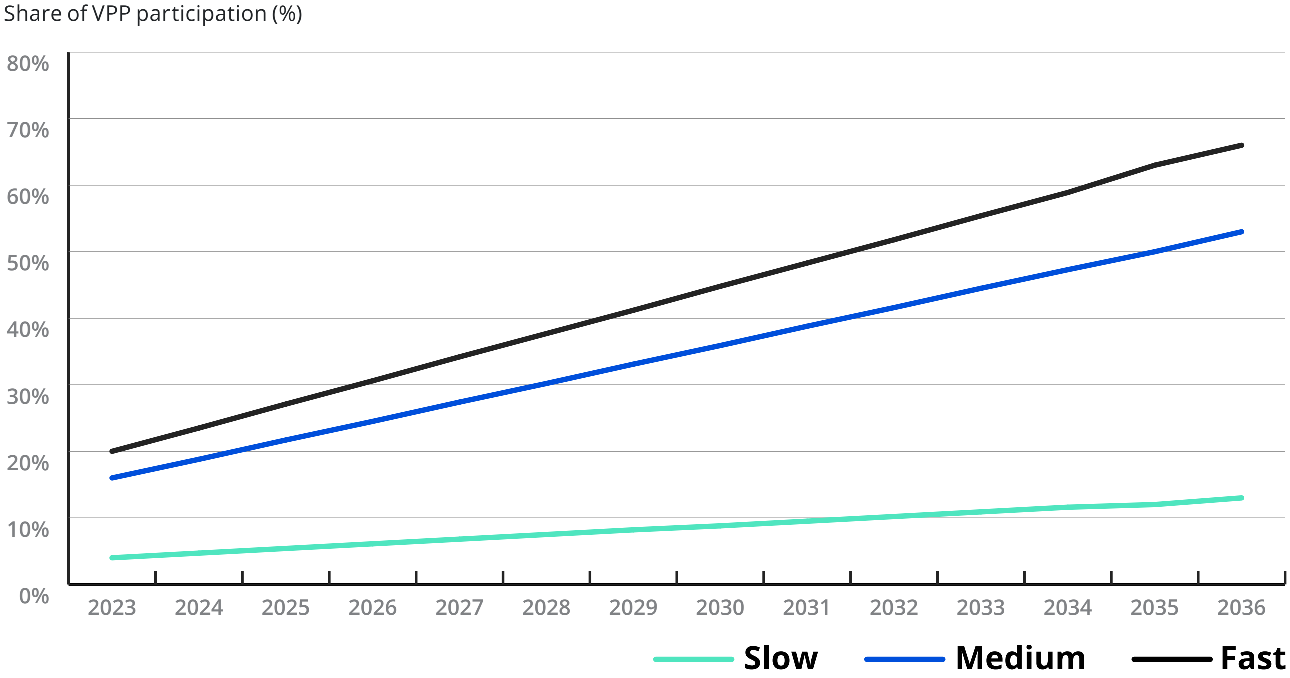
2.2 DER profiles

Battery scenarios depend on the battery's customer and system segment.

In this year's forecast, the residential battery profiles include a growing proportion of batteries participating as virtual power plants over time. VPP participation means that customer battery charge and discharge behaviour is determined by the objective to maximise revenue, rather than to solely maximise self-consumption of energy. This uptake of VPP participation covers three different scenarios — Slow, Medium and Fast — with faster scenarios leading to higher VPP participation. The share of VPP participation for each scenario across the forecast period is presented in Figure 1.

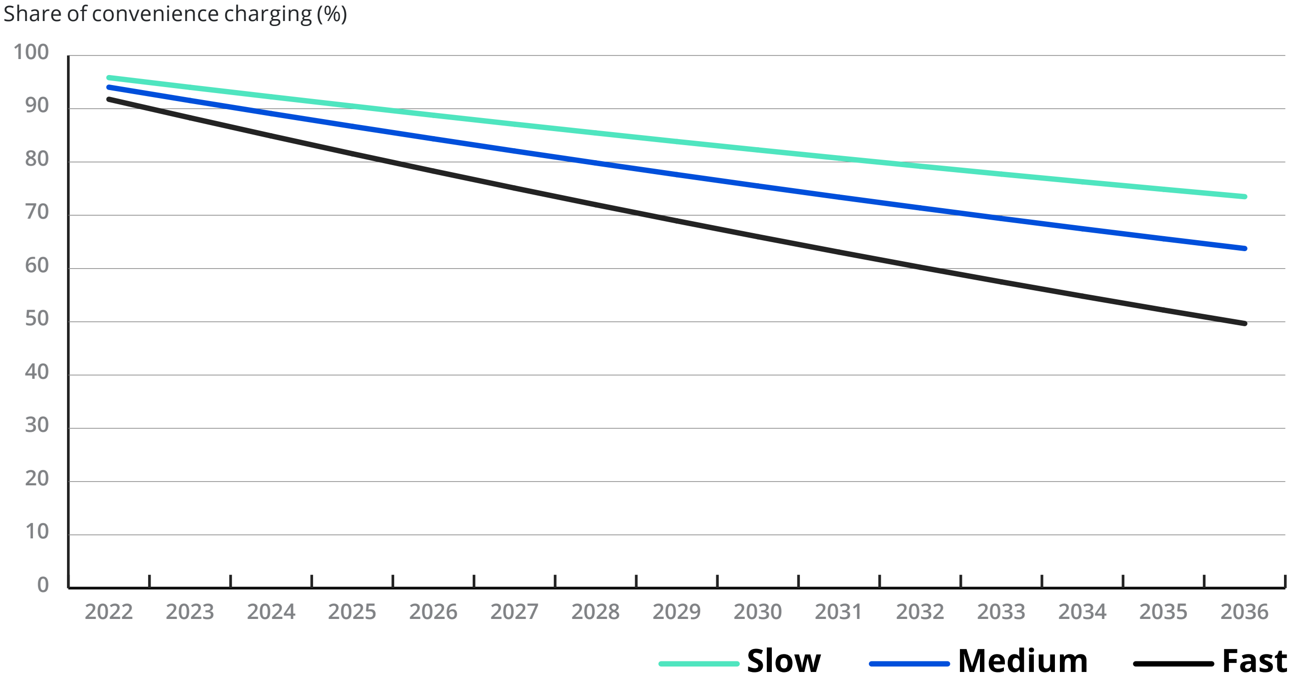
For business and large industrial batteries, there is no tariff change that drives a change in behaviour between scenarios. The average sizes of these systems are forecast to increase over time, however this rate of increase is the same across all scenarios.

Figure 1 — Share of residential battery virtual power plant participation by scenario (%)



Source: AEMO [4]

Figure 2 — EV profile share of convenience charging by scenario (%)



Source: AEMO [5]

The scenarios used for the electric vehicle profile forecasts capture the combinations of different customer charging behaviour types over time. Electric vehicle charging profiles cover three different scenarios — Slow, Medium and Fast — based on the charging behaviours customers adopt. Customers typically adopt one of two charging behaviours:

- **Convenience charging** — vehicle owners charge based on their individual preferences and convenience, with no — or limited — cost-reflective tariffs and pricing signals incentivising when customers charge. Convenience charging typically indicates a preference for charging during the evening peak after returning from work or other daytime activities.
- **Collaborative charging** — vehicle owners are encouraged to charge within specific windows of time, with price signals in place to incentivise 'good' charging behaviour from a network perspective. It is assumed that the incentives and technology to manage charging will exist, to enable an increasing share of collaborative charging over time.

A combination of the convenience and collaborative charging profiles is used to develop scenarios for the DER load profiles. Assumptions are made on the share of each profile in the electric vehicle fleet over time, across each of the scenarios. Each scenario represents a glide path, or transition, from convenience to collaborative charging profiles to 2036. Different levels of collaborative charging are assigned depending on the scenario,[6] as presented in Figure 2. The share of convenience charging compared to collaborative charging is based on the Australian Energy Market Operator's (AEMO) 2022 Forecasting Assumptions Workbook for the Integrated System Plan (ISP) [5].

[6] Blunomy's Fast scenario uses AEMO's Hydrogen Superpower scenario, Medium uses Steady Progress, and Slow uses Slow Change.

Data inputs and assumptions

This section outlines the key data inputs and assumptions used in Blunomy's DER forecasts. Blunomy sought to use inputs that are all publicly available, to ensure transparency in the approach for the modelling and simulations. Furthermore, inputs were preferred if specific to Australia and where possible, Queensland. In other words, global averages and generalisations were avoided unless no domestic data could be sourced.

THIS CHAPTER

3.1 DER uptake

3.1.1 Historical installation data

Historical installation data for rooftop solar PV and behind-the-meter BESS was provided by Energex and Ergon Energy Network, from Australia's DER Register.[7] This data was used to optimise the DER uptake models. The ability of the price and non-price drivers to explain uptake — their explanatory power — was also evaluated, against historical installation data.

In the years preceding the introduction of the DER Register, information on inverters and solar PV capacity was manually collected. This data is available through the Clean Energy Regulator.[8]

[7]Australia's Distributed Energy Resource Register, or DER Register, launched on 1 March 2020 and is managed by AEMO. The register is a database of information about on-site DER installations at residential and business locations within the National Electricity Market, or NEM. The information collected provides insight into the number and capacity of DER by region, down to the postcode level [23].

[8]The Clean Energy Regulatory publishes data on the installed capacity by postcode, for small-scale installations. Data dates between 2001 and 2014, for solar PV and energy storage respectively [1].

3.1.2 Technology costs

Solar PV

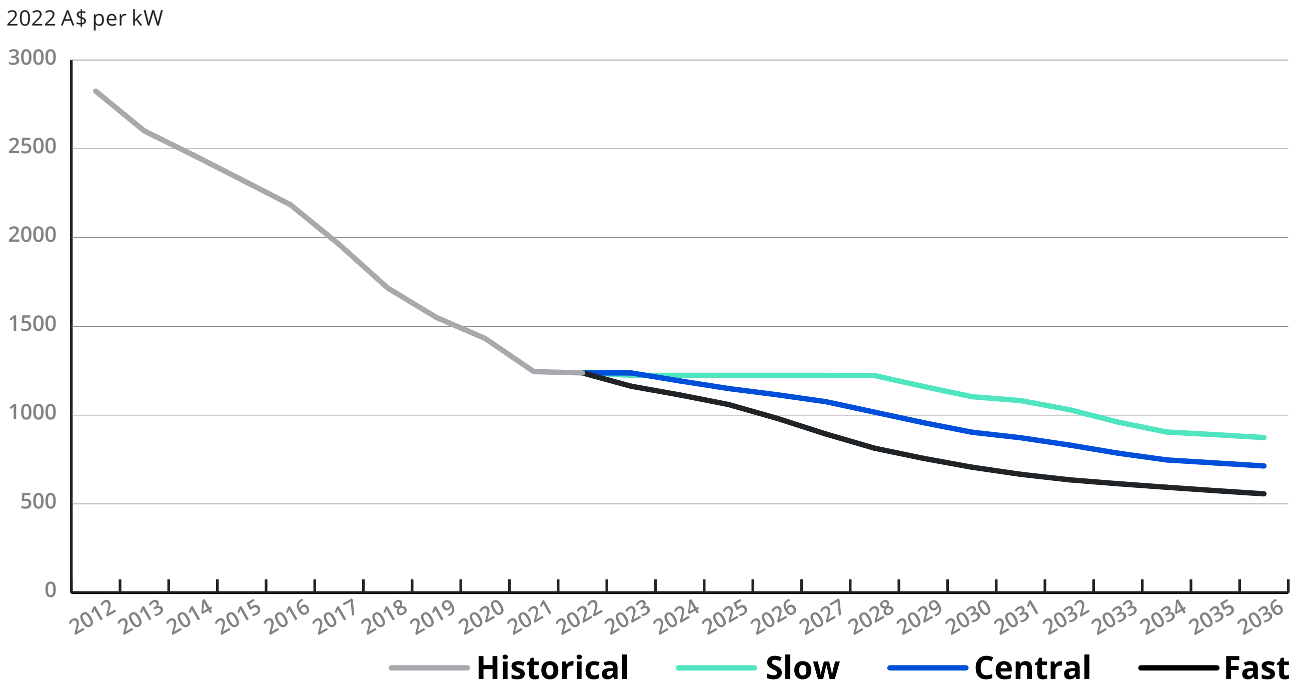
Information on historical costs per kilowatt (kW) for solar PV was sourced from SolarChoice's price index [6]. Future solar PV costs are based on the current and projected technology costs for rooftop solar panels published by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in the GenCost 2021–22 report [7]. This includes using the spread from CSIRO's projections for the forecast scenarios, as shown in Figure 3.

Any upfront government subsidies and rebates that impact purchase price, such as those earned through the small-scale technology certificate (STC) scheme, are excluded from the solar PV technology costs used in the forecasts. Initial modelling of historical solar PV installations without STCs compared to actual historical PV installations (with STCs) shows that STCs impact the timing of uptake but do not affect the cumulative capacity of solar PV installed in the long run.

Further, STCs will be phased out by 2030, and no mechanisms have been committed for the period thereafter. STCs are therefore excluded because of this policy uncertainty, which falls within the forecast period.

The system cost, as opposed to the per kilowatt cost, is used to model solar PV uptake for residential and small business customers. This requires an assumption on the average solar PV system size. Each system is assumed to be 5kW, based on the historical installation data contained in the DER Register and provided by Energex and Ergon Energy. This assumption is used to compare system prices against income as part of the solar PV uptake modelling. For large businesses and large industrial customers, an assumption on the average panel size is not required as the propensity to buy PV driven by technology costs, rather than technology costs compared to income.

Figure 3 — Assumed technology costs for solar PV installation by scenario, excluding subsidies and rebates

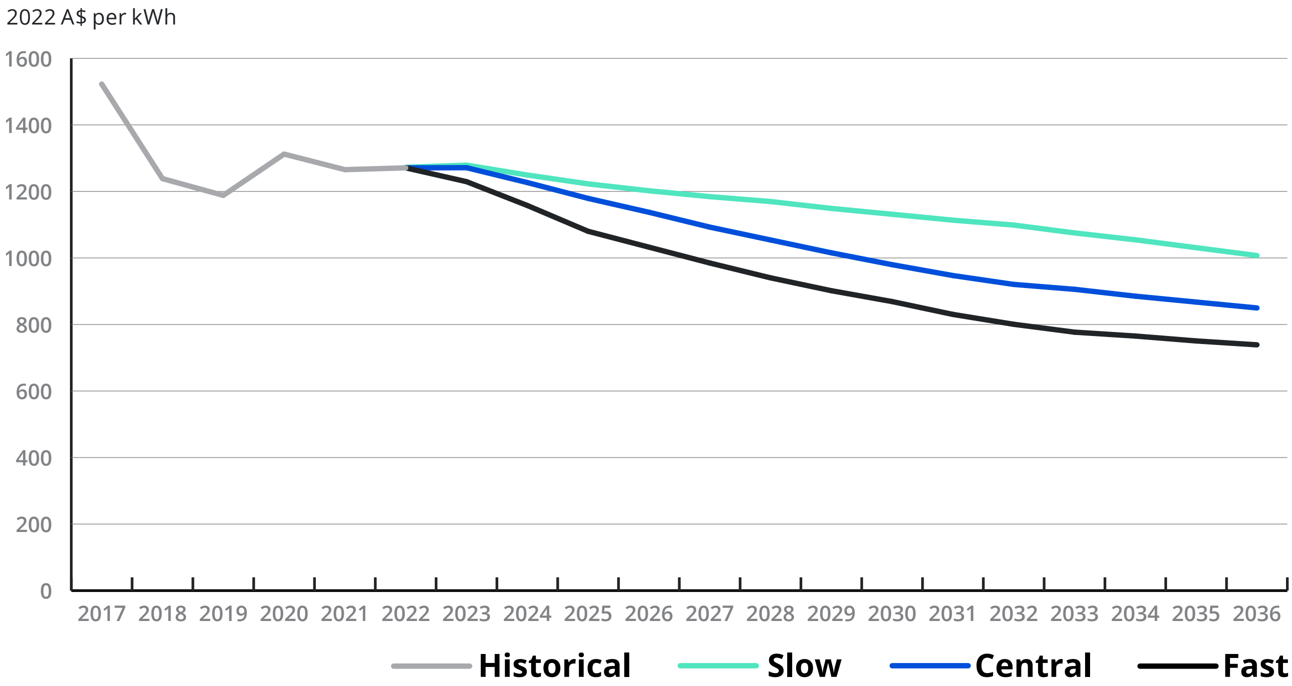


Source: Solar Choice [6] and Graham, P., Hayward, J., Foster J. and Havas, L. (CSIRO) [7]

Battery energy storage systems (BESS)

Upfront costs were used as an input to forecast BESS uptake. Upfront means that the costs do not consider the cost of degradation or disposal at the end of the battery life. Information on historical battery costs was sourced from Solar Choice's battery price index [8]. Future BESS costs are based on the projections published by CSIRO in the small-scale solar and battery projections 2022 report [9]. The lowest cost trajectory presented in the report is selected as the Fast assumption. The Slow scenario aligns with the CSIRO Progressive Change scenario, Central with CSIRO Exploring Alternatives and Step Change, and Fast with CSIRO Hydrogen Export. The forecast technology costs for BESS are shown in Figure 4.

Figure 4 — Assumed technology costs for battery energy storage system installations by scenario



Source: Solar Choice [8] and Graham, P., Mediwaththe, C. (CSIRO) [9]

Electric vehicles

Costs for electric and internal combustion vehicles are based on CSIRO's electric vehicle projections 2021 and 2022 [10] [11], for all vehicle categories except motorcycles. For passenger vehicles, the costs used as inputs in the forecast (and presented below) are assumed to be the average of CSIRO's 'medium car' and 'large/heavy car' vehicle type categories.

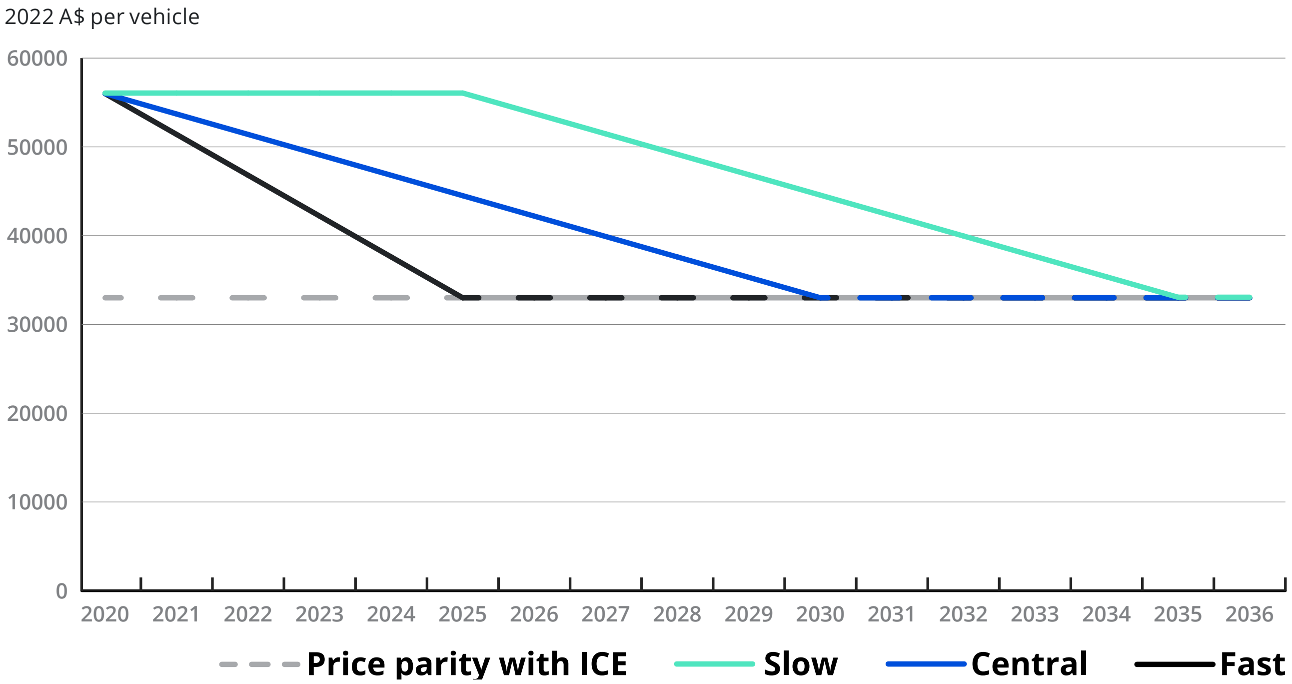
In the case of motorcycles, the average price is based on a scan of the currently available models on the market. The trend and spread from CSIRO's forecast for passenger vehicles is then applied to this average.

Figure 5 shows that the upfront cost of short-range passenger battery electric vehicles is expected to reach parity with internal combustion vehicles in 2030, under the Central assumption.

The Fast assumption brings these cost reductions forward by five years to 2025, while the Slow assumption delays the cost reductions for electric vehicles by five years.

The approach assumes that there is still a gradual increase in the EV market share once the upfront price of an electric vehicle reaches parity with an equivalent internal combustion vehicle. This growth in adoption is expected to be driven largely by non-financial considerations. Although it is possible that electric vehicle costs could reach a point below parity with internal combustion vehicles, this remains highly uncertain. Furthermore, vehicle manufacturers might continue to offer other value-adding features, such as infotainment and additional safety packages, rather than continuing to reduce vehicle prices.

Figure 5 — Assumed technology costs for short range passenger battery electric vehicles by scenario



Source: Graham, P.W. and Havas, L. (CSIRO) [10] and Graham, P. (CSIRO) [11]

3.1.3 Socioeconomic drivers

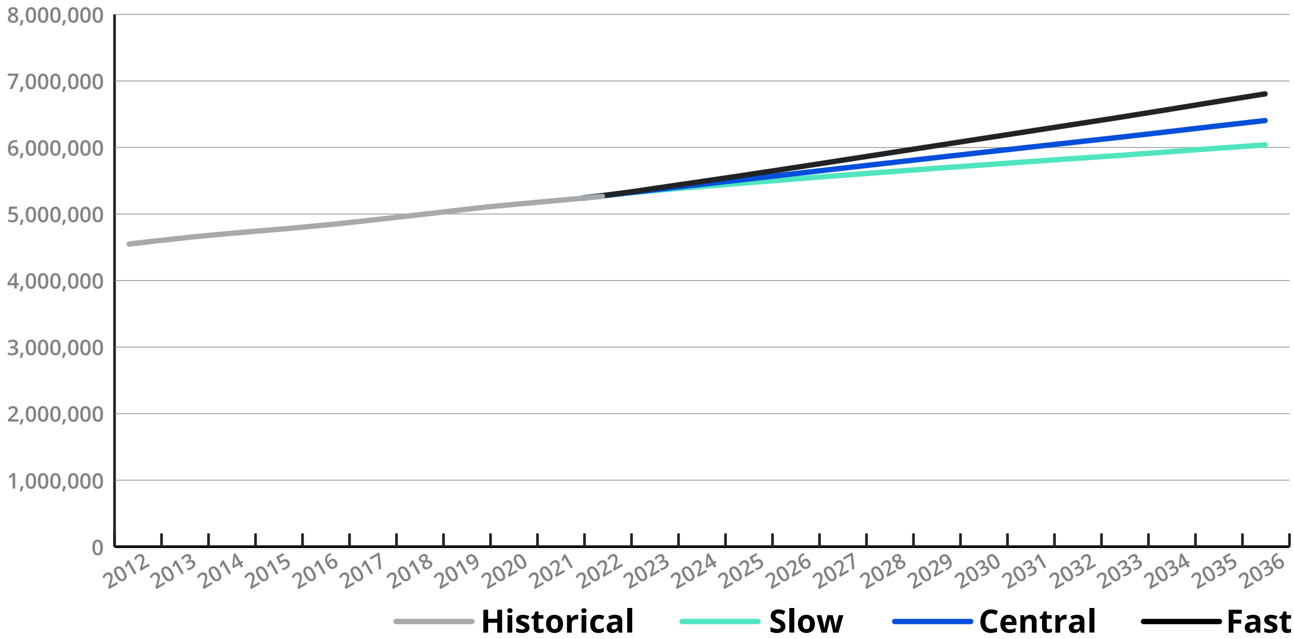
Population

The Queensland population is forecast to continue growing, with the annual increase in population remaining at between 1.5 to just over 1.6% over the next five years. While the rate of growth was slower in 2021 and 2022 compared to the years prior to the COVID-19 pandemic, population growth is predicted to rise again from 2023 onwards. This is shown in Figure 6.

The Central forecast for the Queensland population is based on Deloitte Access Economics December 2022 Business Outlook [12]. The spread from the Queensland Government Statistician's Office population projections has been applied to Deloitte's forecast for the Slow and Fast scenario assumptions [13].

Population is included as key driver for growth in the number of households, as well as the total vehicle stock. As Queensland's population increases, so does the expected stock for both houses and vehicles. The relationship between population and each of these variables is determined based on the historical data — the historical ratio informs the future interactions between population and each variable. This implies that the impact of one additional person on the housing stock remains unchanged, when comparing today (2023) to 2036. The forecasts for the number of households and the total vehicle stock are used in the solar PV and electric vehicle adoption models respectively. The methodology underpinning these models is further detailed in section 4.1.

Figure 6 — Queensland total population forecast by scenario



Household income & gross state product

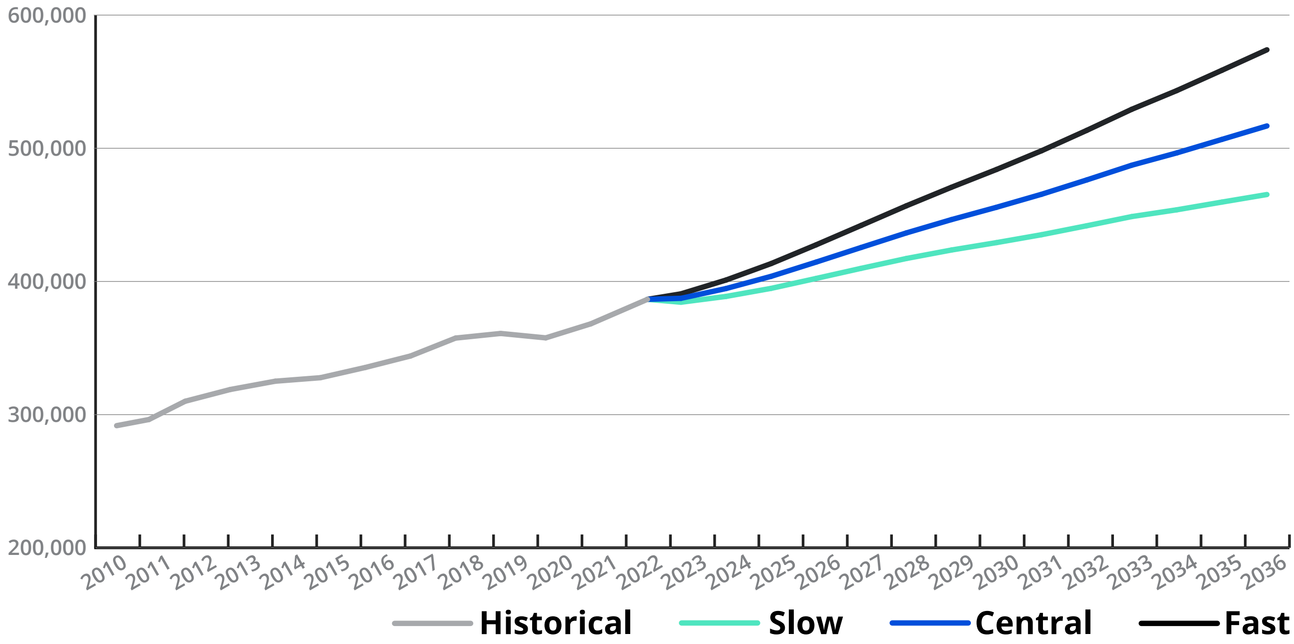
Household disposable income and the distribution of income for Queensland was sourced from the 2021 census data released by the Australian Bureau of Statistics [14]. This was then forecast over time by using the growth in Queensland gross state product (GSP) figures, where this growth is not driven by population growth. The GSP figures are based on the Deloitte Access Economics December 2022 Business Outlook [14]. These figures are shown in Figure 7.

Income is included as a key driver for DER uptake alongside technology costs, in the technology adoption models. Income informs the purchasing power held by residential and small business customers and therefore impacts DER uptake. For example, the decision to purchase a solar PV system is driven by the residential or small business customer's ability to purchase the system, for which income is used as a proxy in the modelling.

Home ownership and household type

Information on the rate of home ownership and household type is sourced from the Australian Bureau of Statistics [14]. These inputs are used to determine the maximum resource potential, based on the proportion of suitable dwellings within the current Queensland housing stock. The maximum resource potential informs the saturation points used in the technology adoption models. For example, it is assumed that apartment dwellers will be unable to install an individual rooftop PV system per apartment.

Figure 7 — Queensland forecast GSP by scenario



Source: Australian Bureau of Statistics [14]

3.1.4 Degradation

Degradation refers to the loss of generation or storage effectiveness over time. As such, degraded capacity (or effective capacity) is the capacity that has been adjusted to take losses due to degradation into account. This implies that the nameplate capacity, or the capacity unadjusted for degradation, grows at a rate higher than what is shown in the forecast results.

Solar PV degradation

Degradation is assumed to be 0.5% annually for solar PV. The degradation rates are based on analysis conducted by the United States' National Renewable Energy Laboratory (NREL) [15].

Battery energy storage system (BESS) degradation

The degradation rate for BESS is assumed to be two per cent annually and is based on analysis conducted by the United States' National Renewable Energy Laboratory [16].

Electric vehicle attrition

Instead of degradation, a vehicle attrition rate is considered in the electric vehicle forecast. The attrition rate captures the estimated proportion of motor vehicles that are deregistered annually. This is also known as the motor vehicle retirement rate.

The vehicle attrition rate is assumed to be 3.12% annually, for all vehicles excluding buses. This is based on the average attrition rate from 2016 to 2021 for Queensland, as reported by the Australian Bureau of Statistics [17]. Vehicle attrition is incorporated into the forecast from year 10 of a vehicle's life onwards, to reflect that the average age of all vehicles registered in Queensland is 10.4 years (as of June 2021[9]). This implies that no vehicles are deregistered between years 0 to 9.

In the case of buses, the total vehicle stock is assumed constant across the forecast period with no growth. This means that the stock in 2036 is equal to the stock in 2023. In the absence of growth in the bus fleet, the attrition rate, or replacement rate, is assumed to be significantly higher at 10% annually.

3.1.5 Renewable energy targets

Solar PV target

As detailed in section 1.2, the Queensland Government has outlined a range of net zero commitments and plans. It is assumed that the Medium solar PV uptake scenario is aligned with the Queensland Renewable Energy Target to achieve 70% renewable generation by 2032 [2]. The 50% renewable generation target is brought forward by two years and achieved in 2028 under the Medium scenario. Under the Slow scenario, 50% renewable generation is reached in 2030 and under the Fast scenario, it is brought forward by four years and reached in 2026.

3.1.6 Solar bonus scheme

The Queensland Solar bonus scheme was a scheme introduced in 2008 that gave eligible customers an ongoing preferential feed-in tariff of 44 cents per kWh until 2028 [18]. The preferential tariff was available to those installing a new system until 2012, when new applicants were not accepted.

As one of the conditions of the scheme was that an eligible customer could not upgrade their system, it is assumed that these customers will not upgrade their system until the end of the scheme on the 1st July 2028.

[9]Future releases of the Australian Bureau of Statistics' Motor Vehicle Census have ceased.

3.1.7 Electric vehicle battery recycling and repurposing

EV battery recycling and repurposing are emerging strategies to manage electric vehicle waste:

- **EV battery recycling** refers to the process whereby materials that can be reused are recovered from EV batteries at the end of 'first life'.
- **EV battery repurposing** refers to the 'second life' use of EV batteries for other applications once they can no longer be used for electric mobility. Possible applications for repurposed EV batteries include battery energy storage systems (BESS).

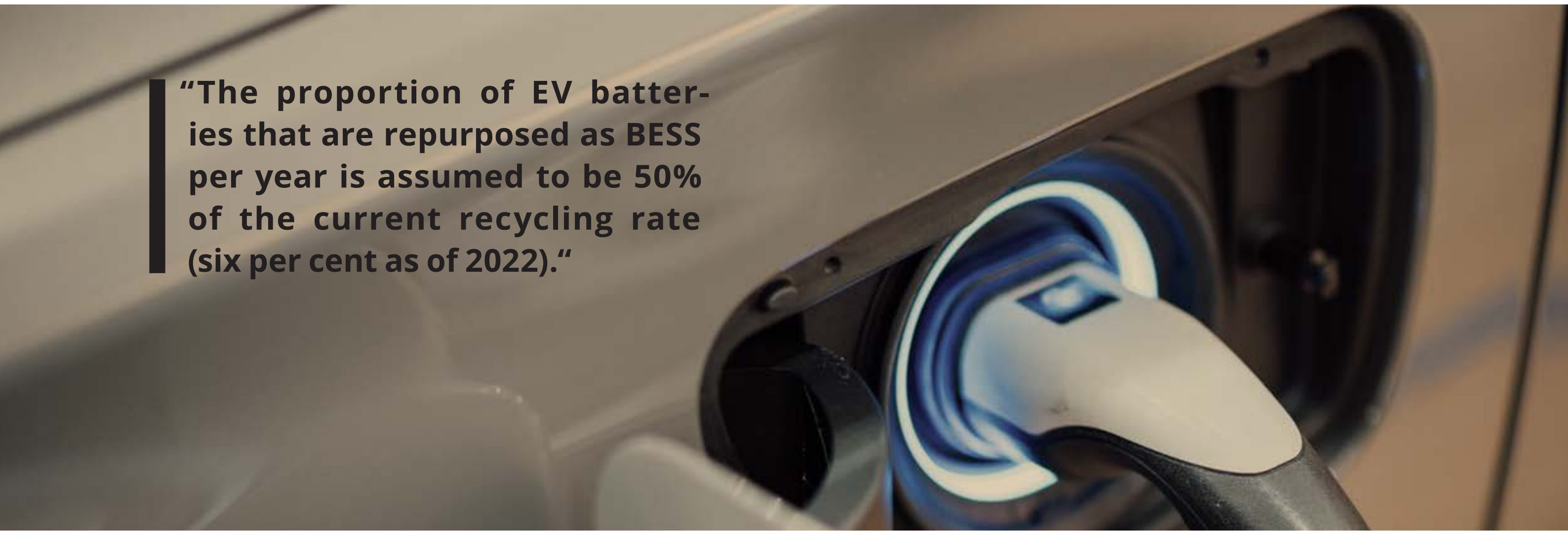
EV battery lifespan and BESS repurposing

The lifespan of an EV is assumed to be ten years, at which point the EV battery can no longer be used for electric mobility. The EV battery capacity at the end of 'first life' is assumed to be 80%.

The proportion of EV batteries that are repurposed as BESS per year is assumed to be 50% of the current recycling rate (six per cent as of 2022) [19]. The additional battery capacity made available from repurposed EV batteries was added to the existing BESS capacity forecast, for customers in the large customer segments (which covers large business and large industrial customers).

3.1.8 Virtual power plants

Virtual power plants, or VPPs, are a cloud-based network of decentralised resources (such as DER and controllable consumer-owned appliances) that are coordinated to deliver power system and energy market services. By aggregating many distributed resources such that they can be monitored, coordinated, and controlled, VPPs can provide the electricity grid with similar capacity and power to a conventional power plant. A growing number of residential customers with BESS are choosing to participate in VPPs, to unlock financial benefits through participation in energy markets. This enables a further revenue source for the BESS, which enables a shorter payback period and an added incentive to purchase a BESS. VPP benefits were assumed to consist of an upfront subsidy of $1250, a payback cost of $200 a year, and a feed-in tariff of 9.8 c/kWh. Values were determined through market analysis and were the average of existing VPP offers.



3.2 DER profiles

3.2.1 Electric vehicle battery sizes

The average battery size for each type of electric vehicle is based on real-world data, where available. For example, the battery size for passenger vehicles is based on data collected through the Queensland EV Smart Charge scheme and shared by Energex and Ergon Energy.[10] Information on the average battery efficiency, for each type of electric vehicle, is sourced from the Queensland EV Smart Charge Scheme and CSIRO's electric vehicle projections 2021 report [10]. These inputs are used to create vehicle travel patterns, as part of the simulations for electric vehicle charging profiles. Battery sizes and efficiencies are presented in Figure 8.

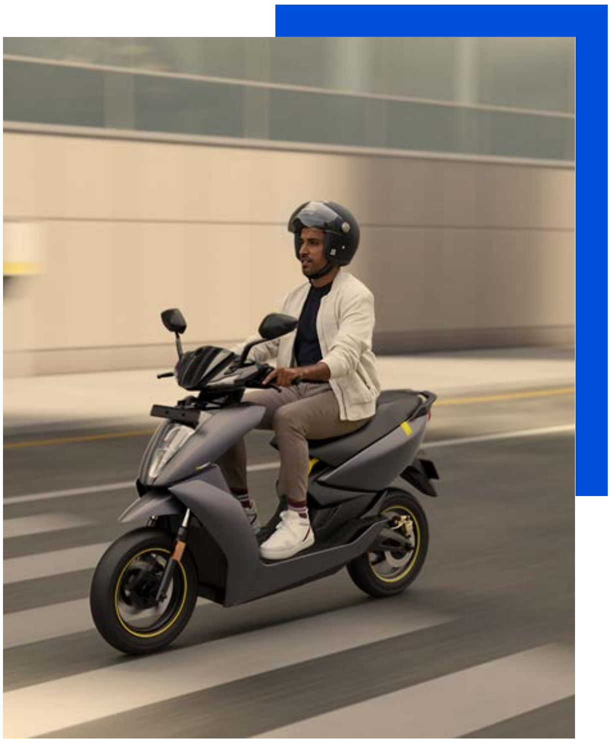
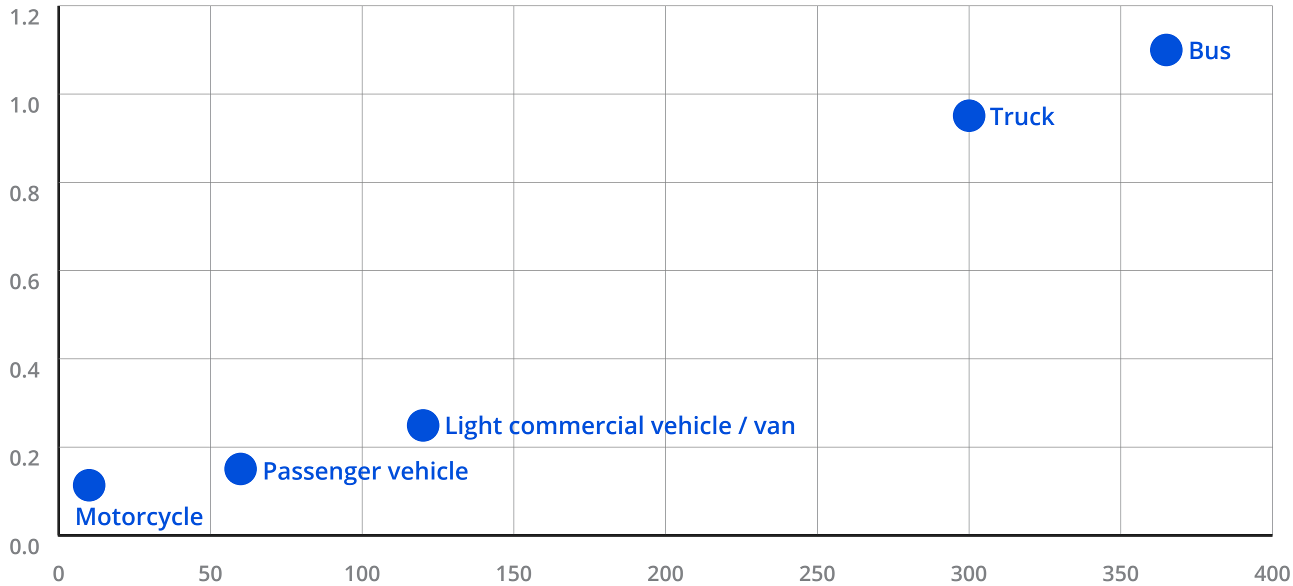


Figure 8 — Assumed battery size and efficiency by vehicle type, in kilowatt-hours (kW)



[10]Where Queensland-specific, real-world data could not be sourced, information was gathered through a targeted literature review and scan of the currently available models on the market [12] [24]

3.2.2 Electricity prices

Individual network tariffs are used to construct the battery operation profiles, following the approach outlined in section 4.2. A range of tariffs and associated operation behaviours are modelled:

- **Residential Solar Sponge** — the battery operates to minimise import from the grid and maximise self-consumption from on-site solar PV generation. This assumes that the import tariffs are higher than the export tariff, incentivising self-consumption.
- **Business Peak Price Avoider** — the battery charges and discharges to minimise energy bills. Time-of-Use tariff data is used and it is assumed that the battery charges from the grid when energy is cheapest during the off-peak tariff window. The battery discharges when energy imports are the most expensive, during the peak window.
- **Business Demand Cap** — the battery charges and discharges to minimise energy bills, similar to the Peak Price Avoider. Demand tariff data is used. It is assumed that the battery charges from the grid when energy is cheapest during the off-peak tariff window. In this case, the battery discharges when energy is the most expensive during the peak window and demand is simultaneously high.

The simulations do not incorporate possible impacts of future tariff reform. For example, DNSPs are now permitted to charge customers for the export of electricity.

3.2.3 Virtual power plants and merchant battery revenues

Following the approach for BESS profiles presented in section 4.2.1 a percentage of residential customers charge profile is simulated for residential batteries participating in a virtual power plant (VPP) scheme,[11] with the percentage depending on the different scenario and year. These batteries, along with large industrial connections over 1.5MVA with batteries, are modelled as virtual merchant, or utility-scale, batteries.

These batteries can provide market ancillary services and participate in wholesale energy trading for battery exports. In these cases, batteries are operated to maximise the available revenues. The approach taken uses the last five years of historical Frequency Control Ancillary Services (FCAS) prices and wholesale prices, optimising the charging and discharging of batteries based on this information.

[11] VPPs are a cloud-based network of decentralised resources (such as DER and controllable consumer-owned appliances) that are coordinated to deliver power system and energy market services. By aggregating many distributed resources such that these can be monitored, coordinated, and controlled, VPPs can provide the electricity grid with similar capacity and power to a conventional power plant.

Methodology

This section provides an overview of the approach for forecasting DER uptake and simulating DER profiles. First, the general modelling approach is outlined. This is followed by a more detailed run-through of the specific steps taken for each technology — solar PV, BESS, and electric vehicles. DER profiles were only provided for BESS and electric vehicles.

THIS CHAPTER

4.1 DER uptake

The modelling undertaken to forecast annual DER uptake is based on the concept of a technology adoption curve, represented by a sigmoid curve — as illustrated in Figure 9. A sigmoid function is a mathematical function with a characteristic S shaped curve, or sigmoid curve. Sigmoid curves are commonly used to model processes that exhibit an initially slow and then accelerating progression that plateaus towards an upper bound, such as the penetration of technology on the market.

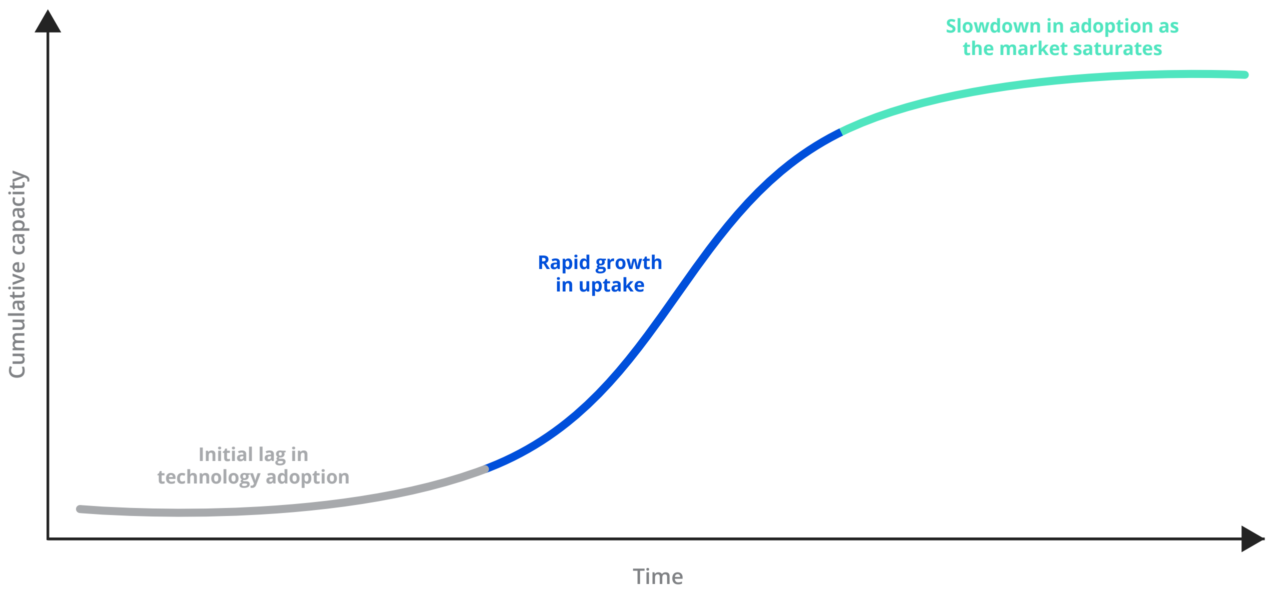
This concept is applied widely as a projection tool incorporating a combination of price and non-price drivers to calibrate the shape of the adoption curve. For example, sigmoid curves have been used by Higgins et. al (2012) in 'Combining choice modelling and multi-criteria analysis for technology diffusion: An application to the uptake of electric vehicles' as well as Higgins, McNamara, and Foliente (2013) in 'Modelling future uptake of solar photo-voltaics and water heaters under different government incentives'.

In the context of this project, the sigmoid curve is used to represent the penetration of rooftop solar PV, behind-the-meter BESS, and electric vehicles on the Energex and Ergon Energy distribution networks.

The sigmoid function is defined by three parameters — saturation, steepness and inflexion. Saturation represents the point at which a given market saturates and is the maximum value that can be reached. The slope of the sigmoid curve is determined by the steepness, which represents the rate of technology adoption. Lastly, inflexion is the year at which the rate of technology adoption begins to slow down. In other words, this is the year during which annual uptake is highest.

The approach is adapted for each DER forecast, optimising the adoption curve using historical installation data to train the model against the relevant input factors. Saturation, steepness and inflexion are all endogenous variables — variables that are determined by the model. This means that the values assigned to these variables are an outcome of the model that are optimised based on the historical data and inputs, as opposed to an assumption.

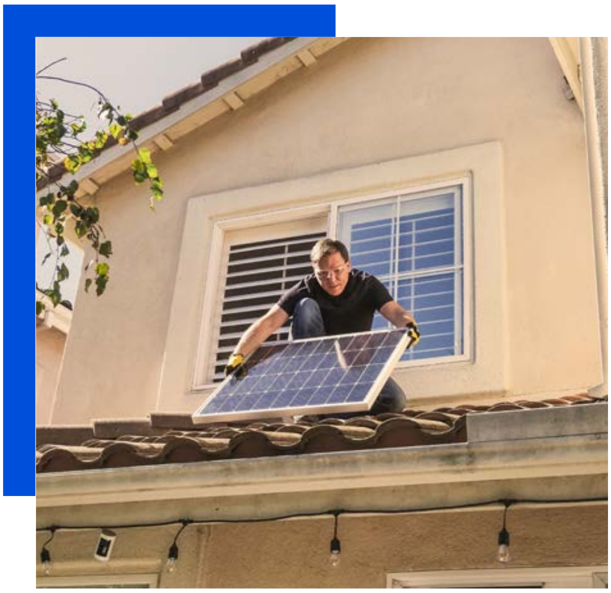
Figure 9 — Technology adoption curve



Once the model is optimised, the rate of adoption is evolved by altering the inputs according to the scenario assumptions outlined in 2.1.

The scenario-based forecasts are all disaggregated from the network level to the feeder level. The disaggregation method used ensures that the historical DER penetration rates across each individual feeder of the network is accounted for in the forecast. One drawback of this method is that it gives more importance to feeders with higher penetration rates (determined by the sigmoid differential), during years in which there is a large increase in DER capacity. An alternative approach is also considered, however this approach would still have a similar drawback.[12]

The following section provides an overview of the approach for rooftop solar PV, behind-the-meter BESS, and electric vehicles. It highlights specific steps in the approach for a given technology that differ from the general approach.



[12]An alternative approach whereby the scaling equation is adjusted to consider the value of the sigmoid instead of its differential, but this also gives more importance to feeders with higher DER penetration rates when the DER forecast is high.

4.1.1 Solar PV forecast

The solar PV forecasting approach follows four modelling steps to determine connection count and capacity forecasts, with the technology adoption curve at the core of the forecast. The first step incorporates the scenarised uptake drivers, or exogenous variables, for two aggregated customer categories for each network. The residential and small business customer segments are aggregated into a single 'small' category. The large business and large industrial customer segments are aggregated into a single 'large' category. This is done to ensure sufficient data points whilst maintaining predictive accuracy, given that each aggregated customer group responds to the same underlying drivers (such as income in the case of the 'small' customer category, and cost savings in the case of the 'large' customer category).

The second step uses a data-driven model. This is used to determine the relative growth rates for the residential, business, and industrial customer segments, for each system segment and network, using historical data. The step produces the connection count forecast.

The third step scales the connection count forecast using the system size forecast. The system size forecast is used to determine the average system size at different points in time. The output of this step is the scenario-based solar PV capacity forecast.

Lastly, the final step disaggregates the outputs of the scenario-based model, using the outputs from the data-driven model. The redistributed outputs provide a forecast of the annual installed solar PV connection count and capacity by customer segment and PV system segment, at the feeder level.

4.1.2 Inverter forecast

The inverter capacity forecast follows two steps. First, the median inverter to solar PV ratio is calculated for each distribution network, customer segment, and PV system segment. This ratio is then multiplied by each feeder level solar PV forecast to determine the feeder level inverter capacity forecast.

The inverter connection count forecast has been assumed to be equivalent to the solar PV connection count forecast. For more details on how the solar PV connection count forecast has been determined, see section 4.1.1 above.

4.1.3 BESS uptake

The battery energy storage systems (BESS) uptake forecasting approach has three modelling steps to determine connection count and capacity forecasts, with the battery's payback period at the core of the forecast. The first step incorporates the scenarised uptake drivers, or exogenous variables that impact the payback period of BESS. These include energy prices, technology costs, and benefits from participating in a virtual power plant. Furthermore, the battery uptake forecast is a function of solar PV uptake. As solar PV technology costs, income, economic growth, and population are the main drivers of solar PV uptake, BESS uptake is therefore also driven by these inputs. The addition to BESS capacity from the repurposing of EV batteries is also considered.

In the second step, the historical ratio of the solar PV connection count and capacity to BESS connection count and capacity is computed for each customer segment. It is assumed that BESS will only be installed with a rooftop PV system, either greenfield or brownfield (as a retrofit). This assumption is based on the underlying cost savings that a battery coupled with solar PV can unlock, by providing access to additional value streams. In the absence of solar PV, the value proposition for BESS is expected to be relatively low.

During this step, a sigmoid curve is fitted to the historical PV to BESS ratio. The BESS capacity forecast is limited by solar PV, as the proportion of BESS to solar PV (by count) will always be less than 1.

Finally, the BESS scenario-based forecasts, for each customer segment and system segment, are spatially redistributed from the network level to the feeder level.

4.1.4 Electric vehicle uptake

The electric vehicle uptake model forecasts the share of annual vehicle sales that will be electric. The relative share of vehicle sales is forecast as opposed to the number of sales, to ensure that uncertainties in estimates for the total stock of vehicles, or the size of the vehicle fleet, are accounted for. An estimate for the number of electric vehicles is still provided, based on a forecast of the total number of vehicles (stock) for each vehicle type in Queensland. The total vehicle stock is calculated using historical vehicle registration data from the Queensland Government Department of Transport and Main Roads [20], as well as both historical and forecast population growth data.[13] Any changes made to this forecast will impact the forecast number of electric vehicle sales, however will not impact the forecast share of vehicle sales.

The process for forecasting electric vehicle uptake comprises several steps, around the principal step of fitting a sigmoid curve. In the first step, the lagged price ratio is calculated of internal combustion engine (or ICE) vehicle costs relative to EV costs.

[13] This approach does not consider any changes in the rate of car ownership over time. Changes in the propensity to own a vehicle could come about due to continued growth in car sharing (such as through Car Next Door) and ride-hailing, for example Uber. The approach also assumes that alternative forms of transport such as trains are complementary to car ownership, as opposed to substitutes.

A lag of one year is applied to EV costs, to take non-price factors that impact the consumer's purchasing decision into consideration. Such factors include vehicle availability, range anxiety, and other constraints consumers may need to overcome. The price ratio considers the costs of both plug-in hybrid vehicles — known as PHEVs — and battery electric vehicles — known as BEVs — within the average EV cost.

Historical electric vehicle sales data, sourced from the Department of Transport and Main Roads, is then used to estimate the relationship between prices and EV electric vehicle uptake. The coefficient reflects the changing influence of declining EV costs (compared to ICE vehicle costs) on EV sales over time. After price parity, EV sales will continue to grow in market share as uptake progresses along the technology adoption curve. In parallel, the number of ICE vehicles available on the market is expected to decrease over time.

A sigmoid curve is then fit on the share of new car sales that are electric, using the last three years of historical sales data for all vehicles (also from the Department of Transport and Main Roads). Although there is a longer time series of data available for total car sales, there is only approximately three years of historical data available that includes information about electric vehicle registrations. The share of new car sales that are electric is modelled for residential and business customers, for each vehicle type — motorcycle, passenger car, light commercial vehicle and van, truck, and bus.[14]

The split between plug-in hybrids and battery EVs is also applied to the EV electric vehicle sales forecast. The share of plug-in hybrids is expected to trend towards zero and is forecast to continue declining over time.

This is in line with the historical trend in vehicle registration data for Queensland as well as observations in other countries with more developed EV markets. The cumulative EV uptakes also consider the separate growth rates of QFleet passenger vehicles and TransLink buses, as well as a vehicle attrition rate of 3.12% per year.

Finally, the forecast is disaggregated from the network to the feeder level. After aggregation of feeders, the ratio of EVs in the Energex area to Ergon area was approximately 10:1.

[14] It is assumed that residential customers will only own motorcycles, passenger cars, and light commercial vehicles and vans (which include utility vehicles, or utes). Business customers could own trucks and buses, in addition to the vehicle categories already listed.

4.2 DER profiles

4.2.1 BESS profile construction

The operation of battery energy storage system (BESS) was simulated for each day in the forecast period, along with each customer category, system size and tariff category / mix using a multi-step approach. The approach to construct the BESS profiles is outlined in this section, with one of the resulting profiles presented in section 5.

Firstly, a battery optimisation pattern was constructed for each customer type, system size and tariff category. Each battery optimisation pattern was based on metering data of sample NMIs with PV systems, with the battery pattern being as if the customer had a battery. The patterns are net of battery efficiencies (assumed to be 85%) [21]. For residential customers, the batteries are sized based on the historical ratio of kWh of battery storage to kW of PV installed. For business and industrial customers, the same ratio is used, however the ratio increases over the forecast period based on the historical trend of PV system size growth. This increase, however, is marginal.

A charge profile is then constructed to capture different behaviours, for each of the customer and system segments. Historical NMI load data is used in the battery optimisation model. Charge profiles are constructed based on the underlying assumptions that the energy consumer will seek to minimise its energy bill, or in the case of the merchant battery, maximise its revenue. The battery charging and discharging behaviour is captured in each profile, based on the specified battery optimisation patterns. There is only one profile type per customer segment, which means that varying battery behaviour by scenario is not possible.

Finally, diversified charge and discharge profiles are constructed by aggregating the profiles for each of the individual batteries. For residential households, three scenarios define varying proportion of customers participating in VPP schemes as opposed to self-consumption maximization. A glide path across the years will merge these two types of profiles. For business customers with systems below 1.5 MVA, their behaviour will be influenced by tariff categories that incentivise reducing demand in peak periods, with no difference in behaviour between scenarios. For large industrial customer systems above 1.5 MVA, the three scenarios will apply AEMO's trends of electricity wholesale market prices and historical FCAS market prices, again with each scenario producing the same behaviour.

4.2.2 Electric vehicle profile modelling

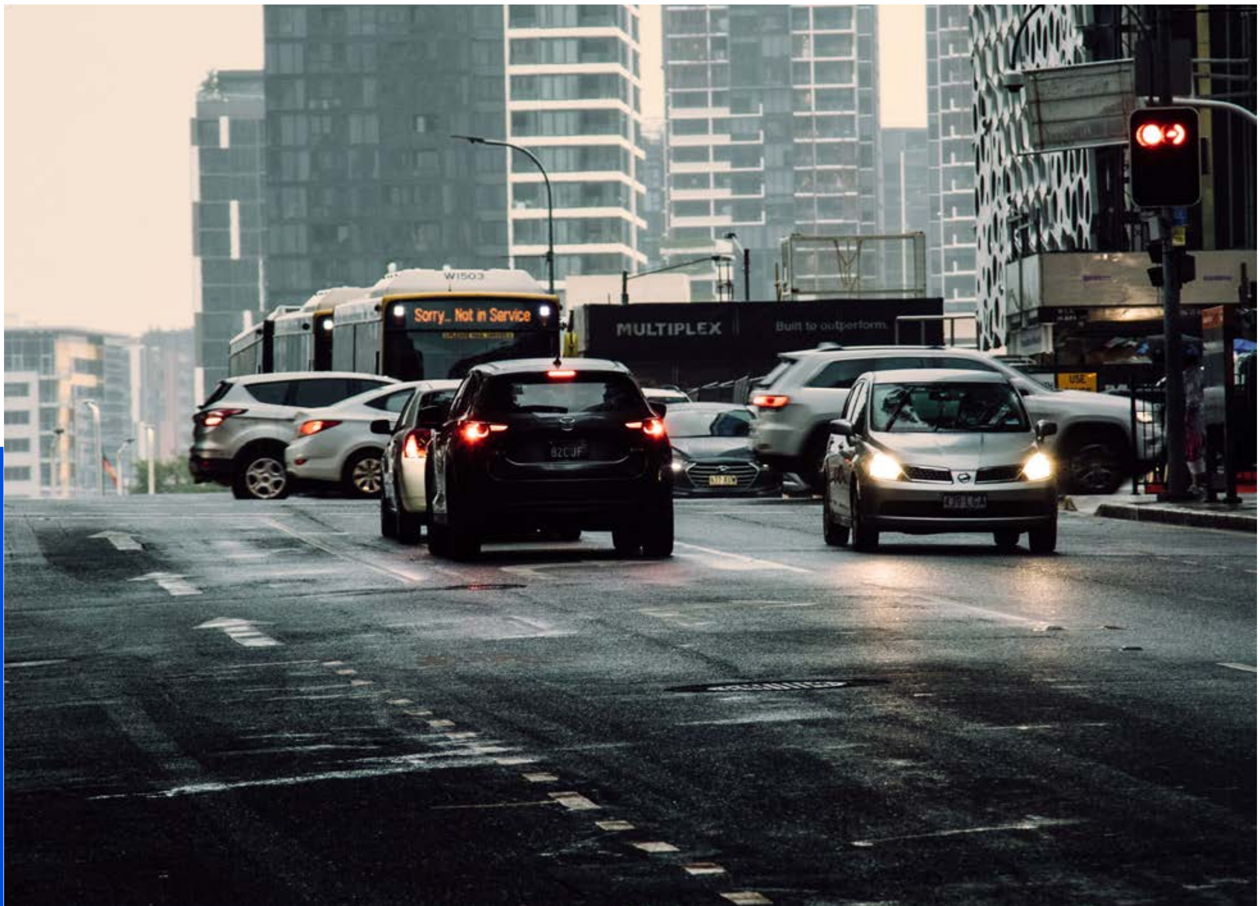
The electric vehicle profile modelling follows four steps, with a charge profile developed for each day of the forecast period. Firstly, a typical vehicle drive pattern is constructed for each vehicle type (motorcycle, passenger vehicle, light commercial / van, truck, and bus) and customer type (residential, business). The travel pattern for each customer type and vehicle type combination is based on historical data (where available) and details the distance travelled (in kilometres) over a 24-hour period, at half hourly intervals. In the case where sample drive data was not available, assumptions were made about the vehicle drive patterns based on the vehicles average annual kilometre's driven, battery size, kWh's consumed per kilometre, and existing drive data.

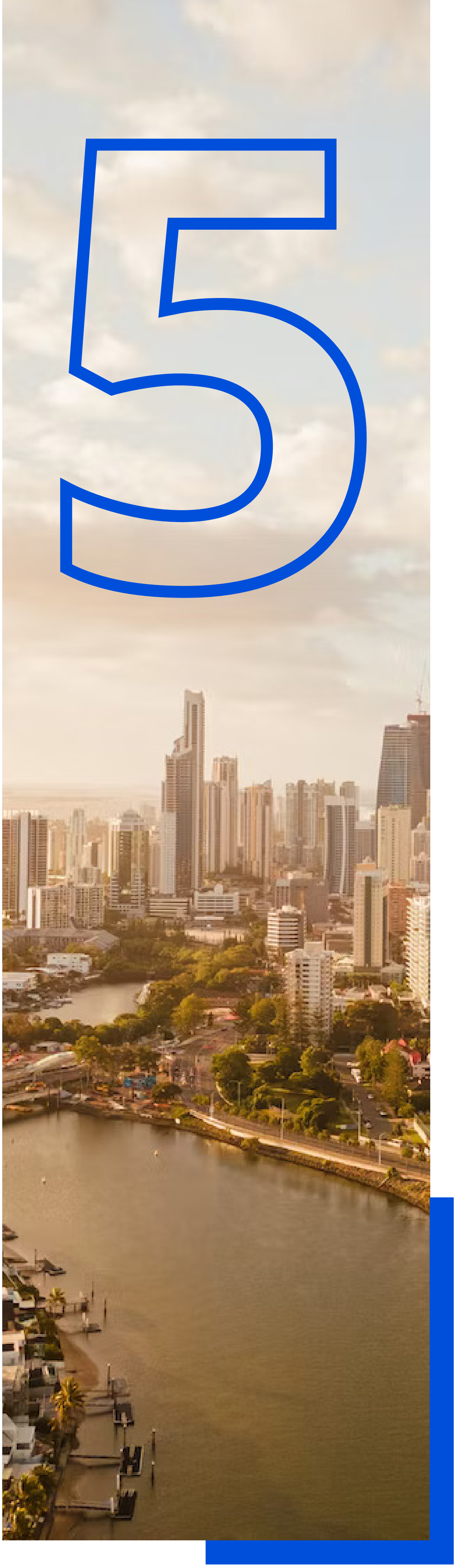
A charge profile was constructed to capture each of the different behaviours for each of the vehicle categories. The profiles capture convenience and collaborative charging behaviour, where convenience charging is driven by the customer's charging preferences (as opposed to price signals) and collaborative charging is driven by price signals (such as Time-of-Use pricing provided by EQL to incentivise 'good' charging behaviour from a network perspective). Each tariff price window is used to correlate the current charging behaviour with energy prices and set the charge windows.

The profiles were generated with further assumptions on charger type adoption (EVSE, 10 amps sockets, public charging stations). Each of these charger types define a specific charging power, and a proportion of usage depending on whether a vehicle is charging in the charging window or out of the charging window.

For each sampled vehicle, a simulation is performed for the first and final years of the forecast using the corresponding adoption rates. The profiles for each year in the forecast horizon are found by a linear glide path between these points.

A combination of the convenience and collaborative profiles was taken to scenarise the profiles, taking assumptions on the share of each profile in the fleet over time (across all the scenarios). The process constructed a glide path from convenience to collaborative profiles in 2036 with different levels of collaborative charging assigned depending on the scenario [5].





Results

This section presents a selection of aggregated results for DER uptake and profiles. Whilst only a single set of aggregated results is shown for each technology, it is important to note that this selection does not provide the complete breakdown of results for each of the individual customer categories, system segments, and behaviour types.

THIS CHAPTER

5.1 DER uptake

The results provided in this section present the forecasts to 2036. For both solar PV and behind-the-meter BESS, the degraded capacity is shown. In the case of electric vehicles, the deregistration or attrition of vehicles is accounted for.

5.1.1 Solar PV uptake

The forecast connection count and capacity of solar PV for Energex and Ergon Energy are shown in Figure 10 and Figure 11 respectively. The forecasts include all solar capacities from systems installed by residential, business, and industrial customers. Historical data from recent years showed strong signs of growth across all customer categories.

Falling solar PV costs are driving continued uptake across all customer categories. Currently around 33% of residential and small business customers connected to the Energex and Ergon Energy networks have solar PV systems. In the Medium scenario, it is forecast that by 2036, over 1.6 million customers (or 70 percent) will have solar PV systems installed. In the Fast scenario, the share of small customers with solar PV could reach as high as over 80%.

The current forecasts are higher across all three scenarios compared to the previous year's forecasts. This is due to Queensland's Renewable Energy Target (QRET) [22]. As specified by the target, the total renewable energy as a percentage of energy consumption should hit:

- Slow scenario: 50% renewable energy by 2030
- Medium scenario: 50% by 2028, 70% by 2032
- Fast scenario: 50% by 2026, 70% by 2030.

Figure 10 — Aggregated forecast connection count of solar PV in the Energex and Ergon Energy networks

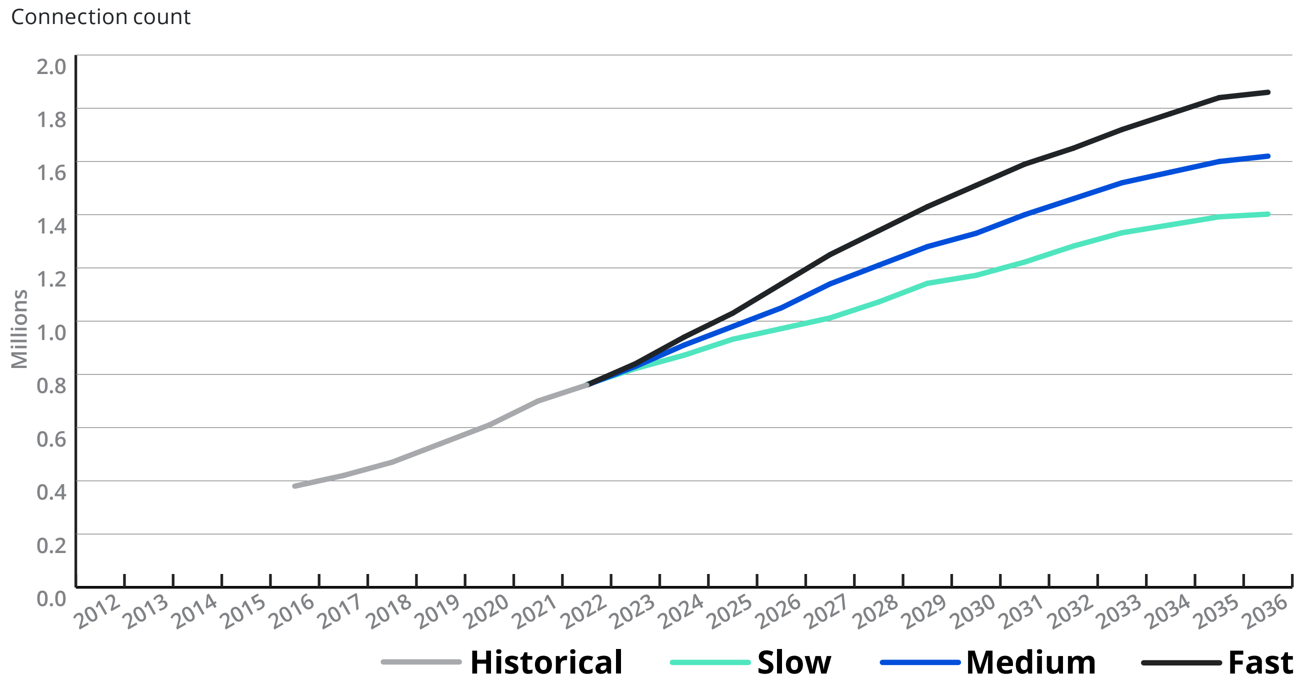
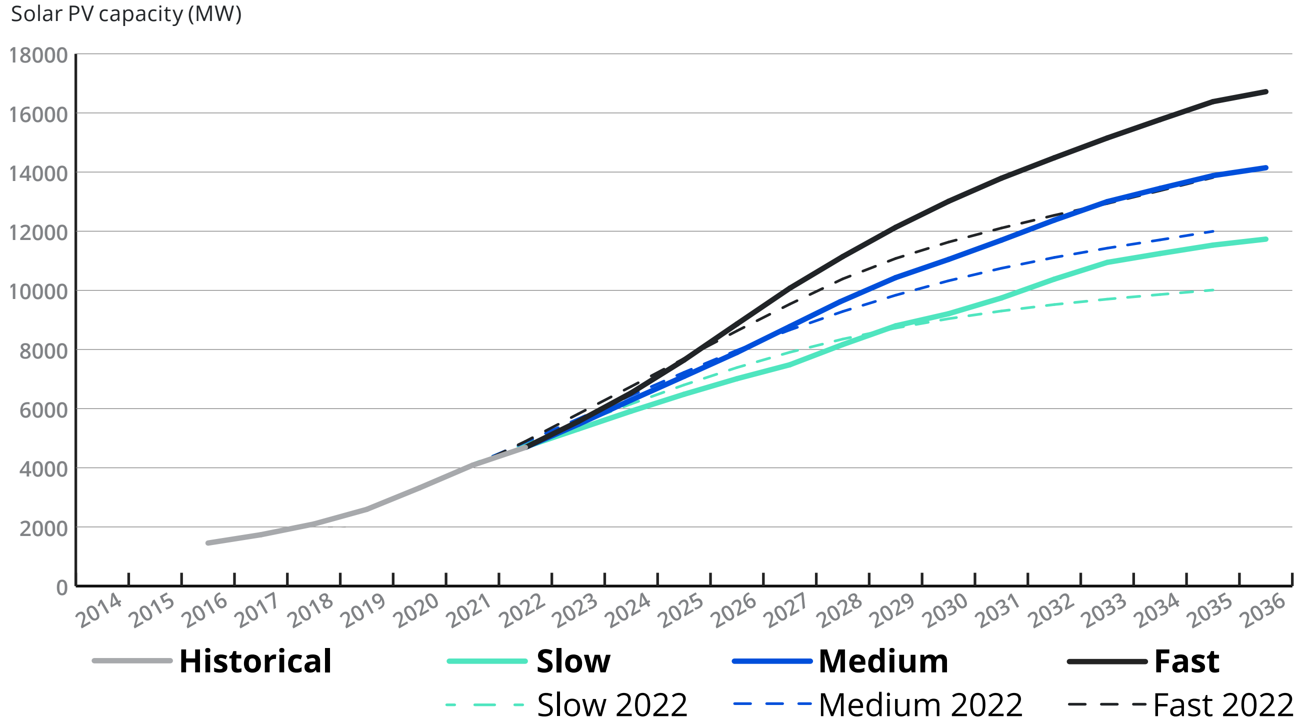


Figure 11 — Aggregated forecast capacity (MW) of solar PV in the Energex and Ergon Energy networks



5.1.2 BESS uptake

The forecast connection count and capacity of BESS for Queensland are presented in Figure 12 and Figure 13 respectively, and include all systems installed by residential, business, and industrial customers. A key positive driver for the growth in BESS uptake is the expected decline in battery costs. Although these cost reductions are highly uncertain, it is expected that costs will continue to decline over time. A slow-down in this decline is expected from around 2030 onwards across all scenarios.

All three scenarios exhibit an increase in behind-the-meter storage capacity that is at least tenfold, between 2023 and 2036. In all cases, this increase is driven by strong battery cost reductions.

The Fast scenario is forecast to have the largest addressable market, represented by the number of installed solar PV systems. For customers with solar PV systems installed, over four per cent are forecast to also have batteries installed by 2036, in the Medium scenario. This is compared to approximately 2.5% of solar PV customers currently (in 2022) — noting that there also will be significantly more solar PV customers in 2036 in comparison to 2022. Another key driver for the increase in BESS capacity, especially from 2028 onwards, is the addition of capacities from repurposed EVs.

This year's forecast continues to grow post–2028 compared to last year's due to repurposed EVs. Also, the spread between slow and medium is wider than last year's forecast due to a wider spread of input battery costs.

Figure 12 — Aggregated forecast connection count of battery energy storage systems in the Energex and Ergon Energy networks

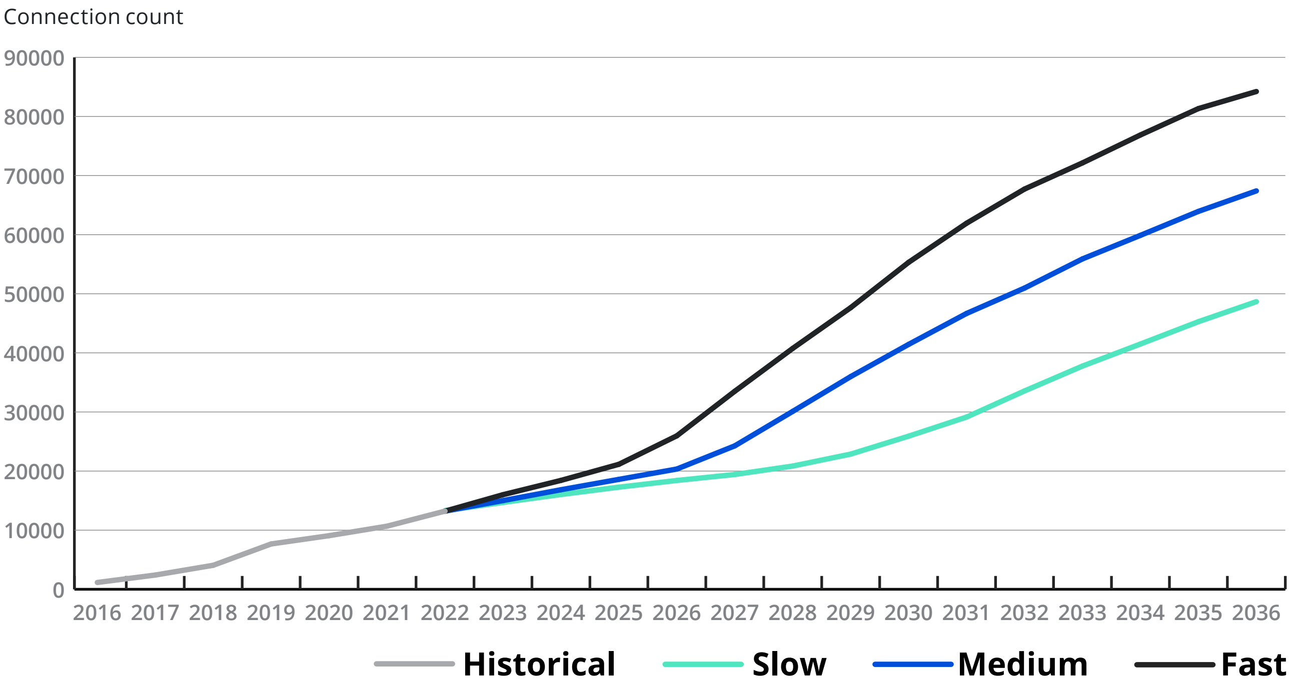
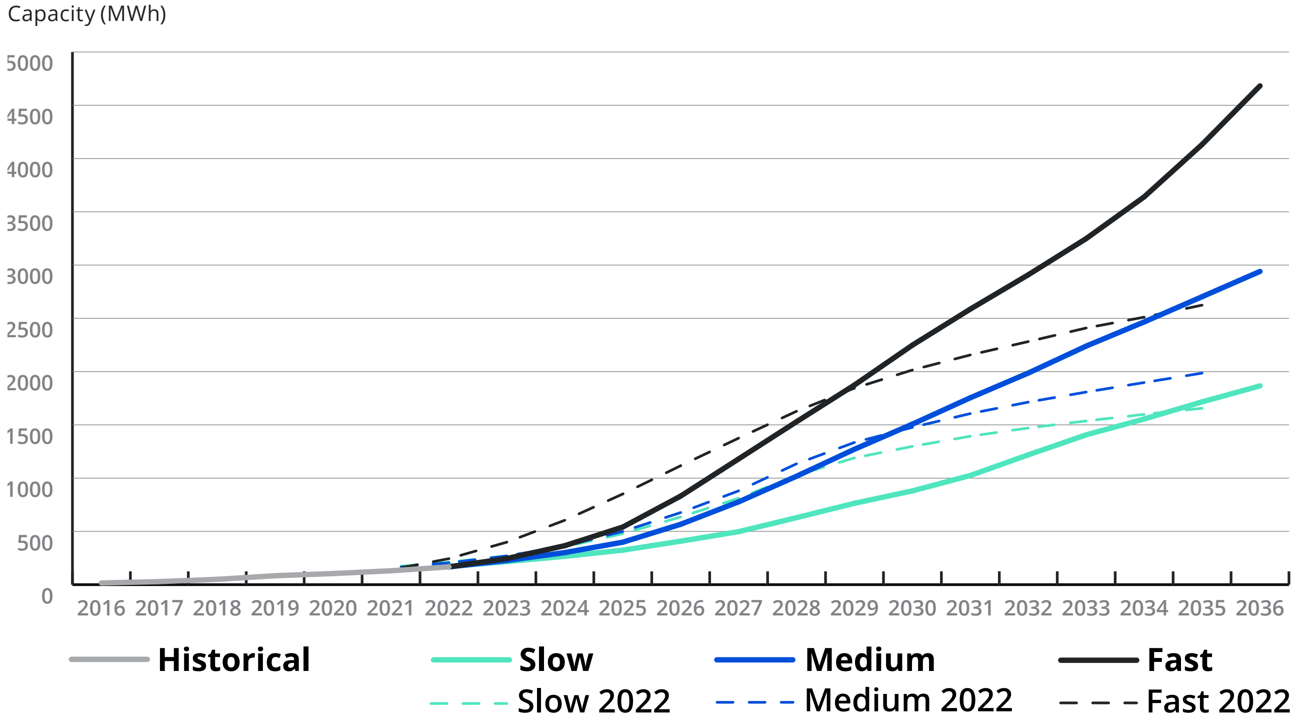


Figure 13 — Aggregated forecast capacity (MWh) of battery energy storage systems in the Energex and Ergon Energy networks



5.1.3 Electric vehicle uptake

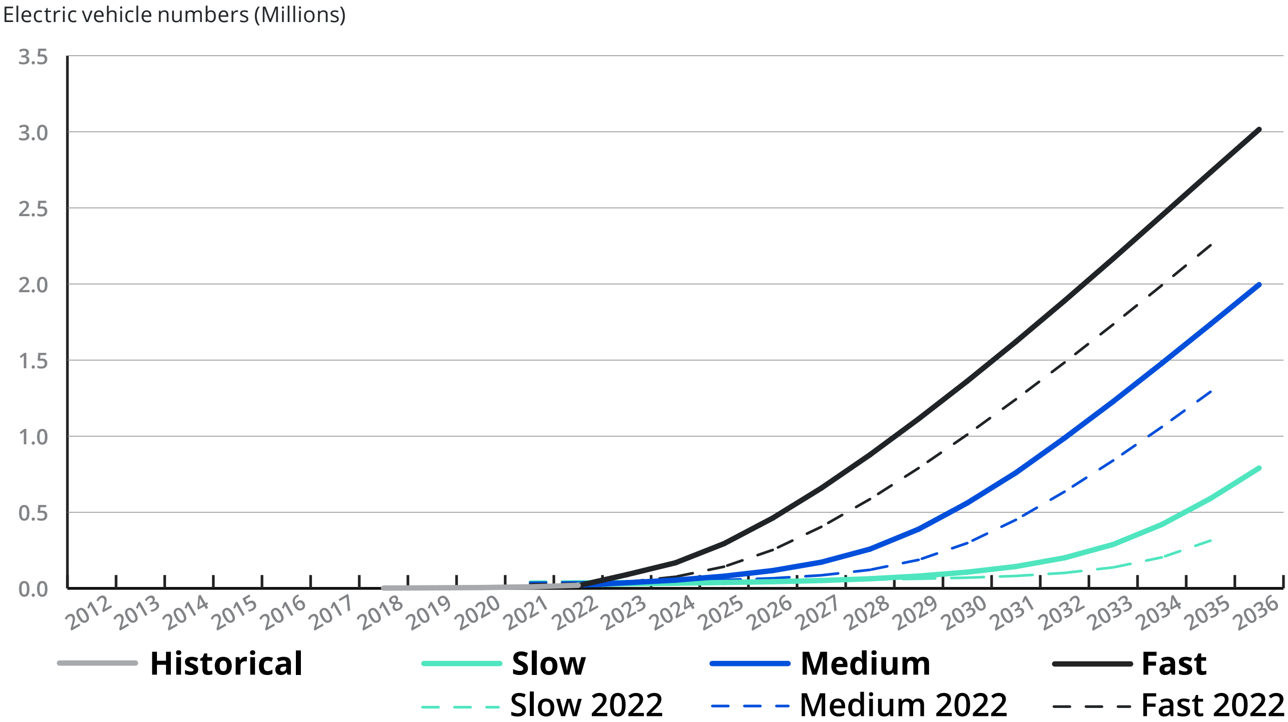
The forecast number of electric vehicles — including battery and plug-in hybrids — is shown in Figure 14. By 2036, there could be as many as 2 million electric vehicles registered across the Energex and Ergon Energy networks, in the Medium scenario. The forecast number of electric vehicles does, however, range considerably between the scenarios. This is due in part to the variation in when price parity with internal combustion vehicles is achieved. It is also a result of differences in the forecasts for the total stock of vehicles, from which the number of electric vehicles in estimated. As previously outlined, the projected sales shares are forecast as opposed to vehicle numbers, to account for the uncertainty in the stock of vehicles.

It is forecast that by 2036, close to 34% of passenger vehicles on the road could be electric, in the Medium scenario.

Compared to 2022's forecast results, current EV uptake forecasts are notably higher across all scenarios. This is largely driven by the Queensland Government's Zero Emission Vehicle Strategy [23], which specifies that:

- 50% of new passenger vehicle sales targeted to be zero emission by 2030, moving to 100% by 2036
- 100% of eligible Queensland Government fleet passenger vehicles to be zero emission by 2026
- Every new TransLink funded bus added to the fleet to be a zero emission bus from 2025 in South East Queensland and from 2025–2030 across regional Queensland.

Figure 14 — Aggregated forecast uptake of electric vehicle counts in the Energex and Ergon Energy networks



5.2 DER profiles

The results provided in this section represent a selection of the charging and discharging profiles for BESS and electric vehicles. Each load profile is provided at a half-hourly interval, across the 24 hours of day.

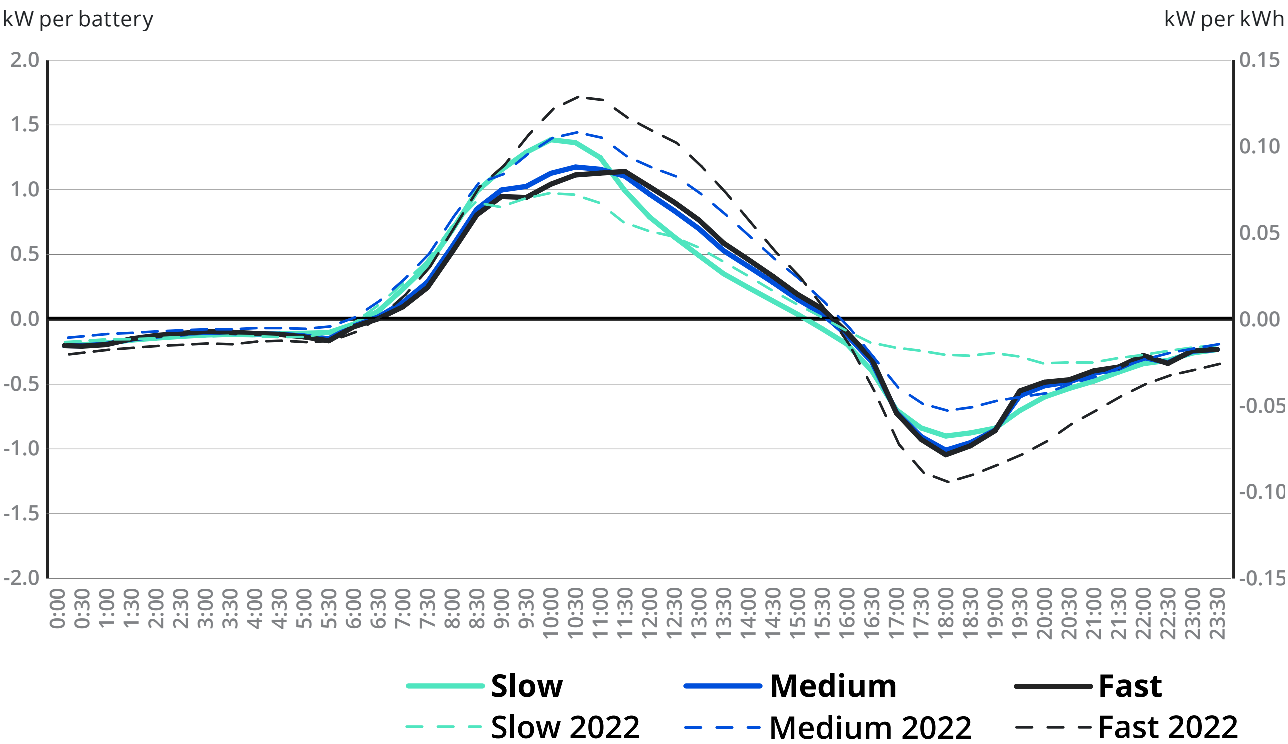
5.2.1 BESS profile

The profile provided in Figure 15 shows the average weekday charging and discharging behaviour in 2036 for small residential customers with system size <= 10kVA. The battery is operating under two key goals – one to maximise self-consumption from on-site solar generation (solar soaker), the other to maximise available revenues from wholesale energy market (as the battery acts as a VPP). The relative focus of the battery depends on the scenario and year, as VPP uptake is expected to grow over time. In the figure, the battery acting as a VPP results in a greater discharge of the battery during evening peak periods, and more variability due to the battery responding to price signals.

Furthermore, while Figure 15 presents the average charge profile across one year, a limited amount of variation in how the battery is operated is expected between summer and winter. This is due to the relative consistency in Queensland's weather over the course of the year. The weather typically impacts both how much energy customers use, as well as how much they can generate — through their solar PV systems.

This year's forecast includes a glide path for VPP participation, which results in charging and discharge patterns being more aligned to market price signals rather than maximising self-consumption. This year's profile was given in units of kW per battery, whereas last year's was given as kW per kWh.

Figure 15 — Average charge profile for 2036 for residential customers with system size <= 10kVA on weekdays

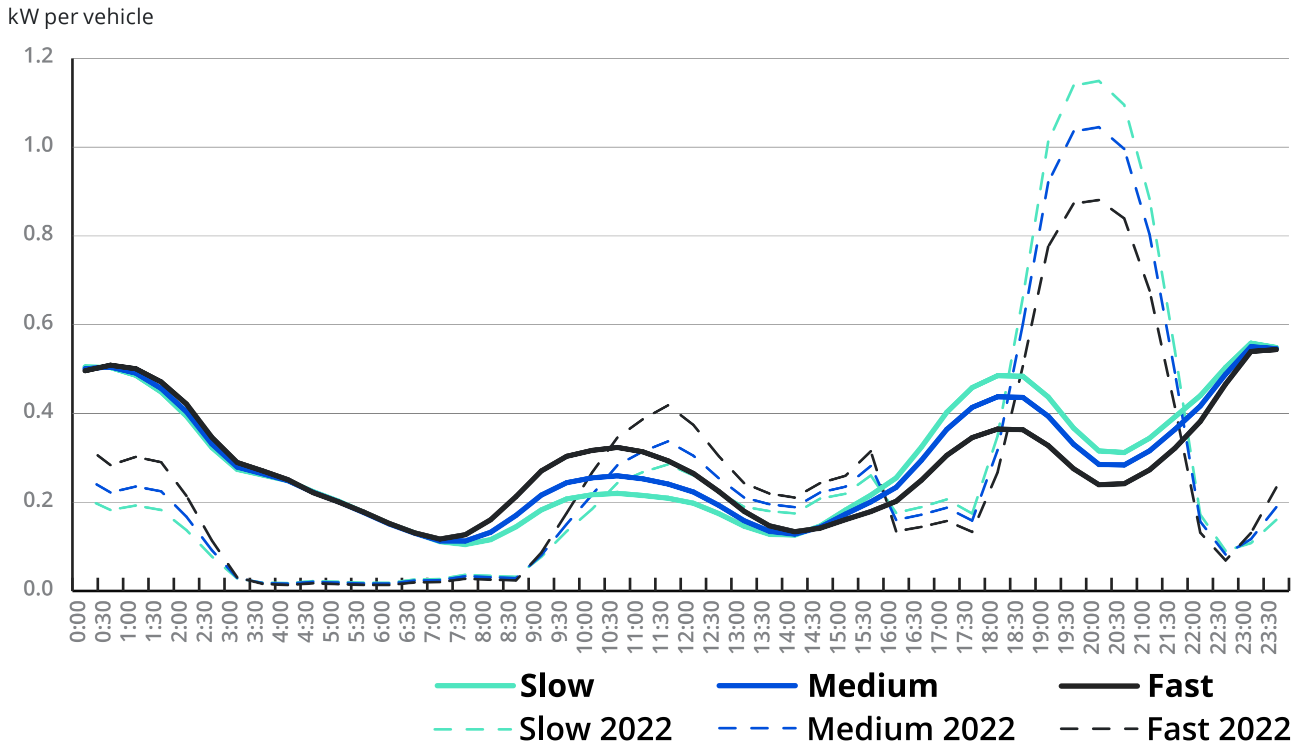


5.2.2 Electric vehicle profiles

The average weekday EV charging profiles for residential passenger vehicles in 2036 are shown in Figure 16. The faster scenarios contain higher proportions of collaborative charging over convenience charging behaviours. Collaborative charging is also expected to increase within each scenario over time. The fast scenario has the highest charging per vehicle in the middle of the day, as a greater share of collaborative charging translates to proportionally more charging during this time, where the customer can take advantage of lower tariffs and higher solar PV production. Convenience charging, on the other hand, results in a high concentration of charging during the evening peak, as can be seen in the slow scenario. This pattern can be seen in both the current forecast and 2022's forecast.

This year's forecasts are considerably smoother than last year's due to adjustments in charging type/speed, higher share of collaborative charging, and much larger sampling during the simulation processes driving greater diversification. The forecast also has more appropriate windows of higher average charging than last years forecast.

Figure 16 — Daily charge profile in 2036 (2035 for 2022 results) for residential passenger vehicles



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