SYSTEM VALUE ANALYSIS

AUSTRALIA

October 2022

accenture

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System Value of the Clean Energy Transition

The System Value framework more holistically evaluates economic, environmental, social and technical outcomes of potential energy solutions across markets. The framework aims to **shift political and commercial focus beyond cost to include value**

Using the System Value framework, the World Economic Forum, supported by Accenture and a group of global electricity companies, conducted analysis across several geographies as part of market evaluations that examined recovery opportunities to accelerate economic growth and the clean energy transition.

The flexible nature of the framework allows inclusion of both quantitative and qualitative analysis. The relevance of System Value dimensions may vary by geography and over time horizons.

Economic, environmental, societal and energy value

Note: Above hexagons represent desired outcomes

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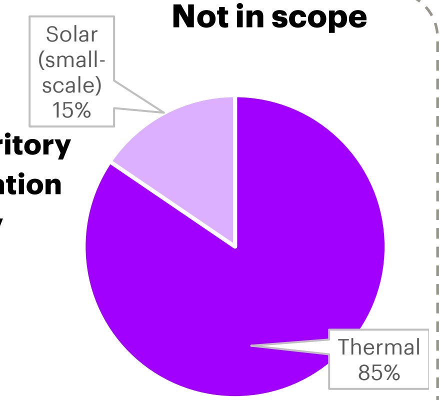
System Value Analysis Focus

The National Electricity Market (NEM) is the focus for this SVA. The Australian National Electricity Market (NEM) spans across five interconnected states on the eastern and south-eastern coasts including South Australia, Victoria, Queensland, New South Wales, Tasmania and the Australian Capital Territory. It is responsible for approximately 90% of Australia's electricity generation capacity[1]

AUSTRALIAN ELECTRICITY MARKETS

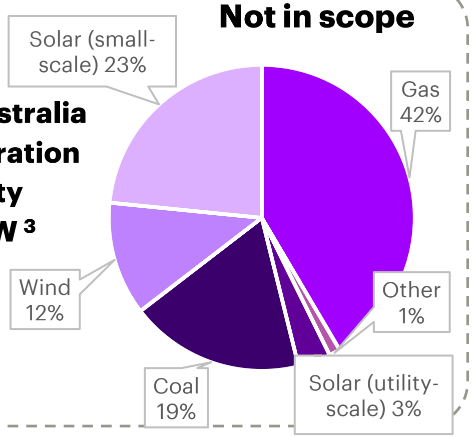
Not in scope

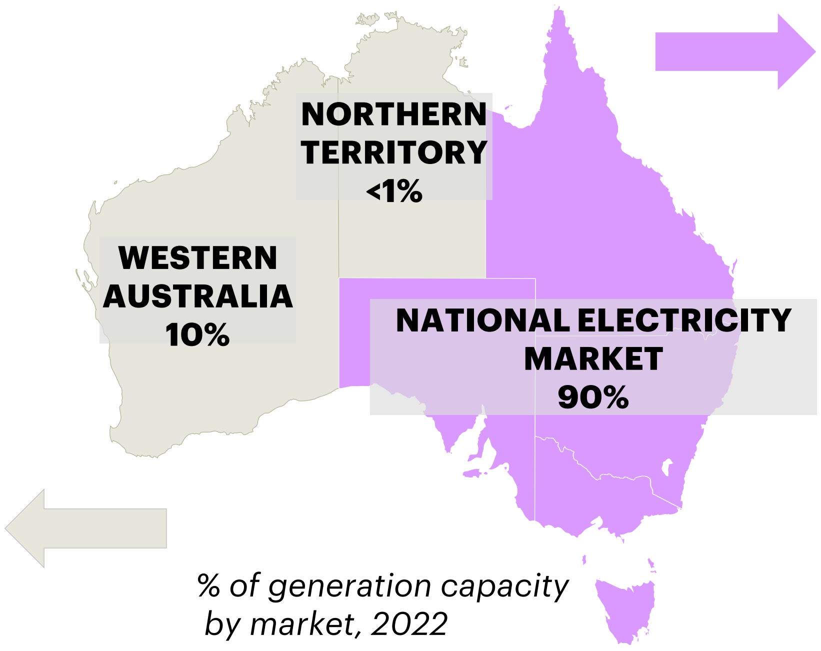
Northern Territory 2020 Generation Capacity 504 MW (2020)[2]



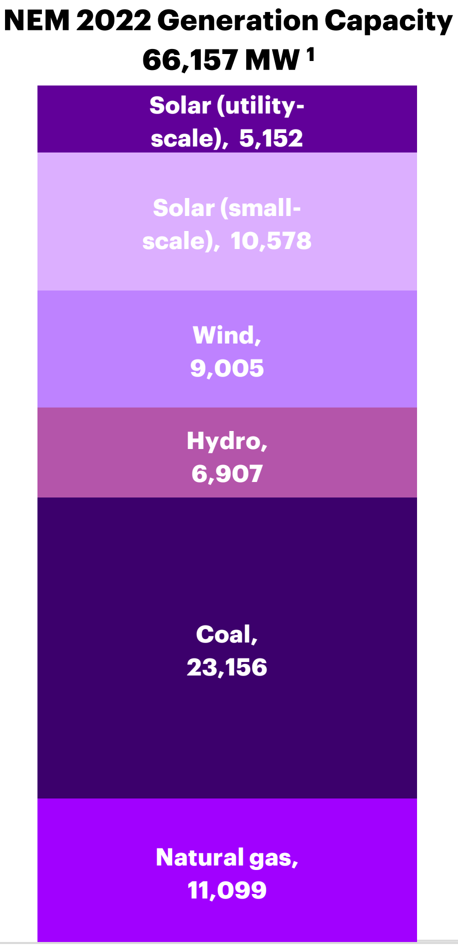
Not in scope

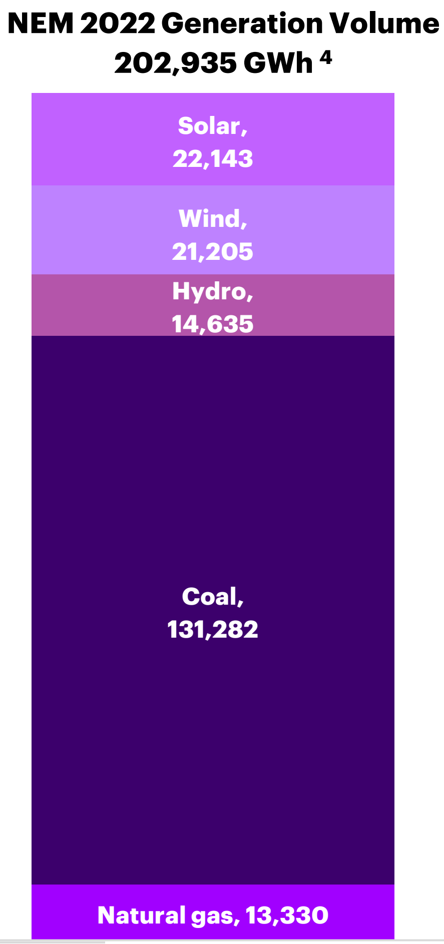
Western Australia 2022 Generation Capacity 7433 MW[3]





% of generation capacity by market, 2022





Source: 1. AEMO ISP 2020 Generation Outlook, Central, 2. Darwin-Katherine Electricity System Plan (October 2022), 3. AEMO, Wholesale Electricity Market ESOO (June 2022), 4. OpenNEM generation data

Australia Electricity Market Structure

The NEM operates as a vertically disaggregated market with full retail and wholesale (generation) competition. Transmission and distribution are regulated by the AER and the market operator AEMO is manages the energy systems and markets

Generation

Transmission

Distribution & Retail

End Consumption

Regulator: Australian Energy Regulator (AER), Operator: Australian Energy Market Operator (AEMO)

The **AER** is responsible for approving revenue for services that will allow households and businesses access the energy they need at the lowest cost. The **AEMO** is responsible for selecting the lowest cost of generation in the **spot market** to run through the transmission networks in the NEM.

Generation

The **AEMO** decides which generator will be deployed and provides dispatch instructions to the generators

A total of approximately 200 electricity generators in the NEM jurisdictions

Fossil Fuel (71%)

Self-generation (29%)

Transmission

- Powerlink (QLD)
- TransGrid (NSW & ACT)
- AusNet Services (Vic)
- ElectraNet (SA)
- Transend (TAS)

There are **5 state-based transmission network service providers (TNSPs)** in the NEM. They link generators to the **13 major distribution networks** that supply electricity to customers

Distribution & Retail

DNSPs send electricity to residential and other buildings through lines and wires

13 Distribution Network Service Providers (DNSP)

Over 33 Electricity Retailers

Retailers purchase electricity from the NEM and re-sell it to end-use customers

End Consumption

- Residential
- Commercial
- Industrial

The **AEMO recovers costs** from customers that purchased electricity from retailers

Households with solar PV systems

Self-generating customers can sell excess energy back to retailers or neighbours, or offer demand response

Legend: Government | Private Companies | Customers

Source: AEMO (2021), AEMC (2013), AER (2021)

The Australian Market

2050 All Australian states and territories have committed to net zero by 2050, whilst the *Climate Change Bill 2022* has enshrined this goal at a federal level, alongside a 43% reduction on 2005 levels by 2030

60% Coal currently dominates 60% of current energy generation, primarily in older unreliable plants. However, announced closures will see **~15 GW** of coal exiting the market by 2035

25 GW International investors have identified opportunities for over 25 GW of offshore wind projects[1]

>3m Australia has the world's highest rate of residential solar panel uptake, with over 3 million households connected to the NEM.

27% Electricity generation in the National Electricity Market is responsible for **27%** of Australia's carbon emissions

25% Transport and stationary energy sectors (amenable to electrification) comprise **25%** of Australia's carbon emissions

2.5% per yr Currently estimated reduction in gas usage per year attributable to fuel switching (gas to electricity)

30% Industrial processes currently consume roughly **30%** of the NEM's electricity

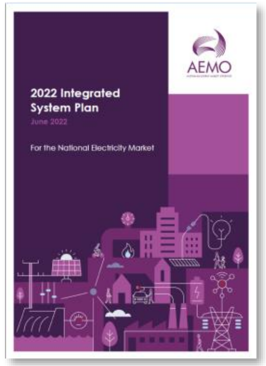
1755 TWh Current yearly energy usage in Australia

>10K km Transmission lines targeted to be built over the next decade

[1]Note: References are provided in the Market Analysis section of this document

Australia’s electricity supply is decarbonising rapidly

Renewables are – finally - replacing coal at an extraordinarily fast pace, which is set to continue as the renewable energy generation becomes the dominant source of energy for the NEM



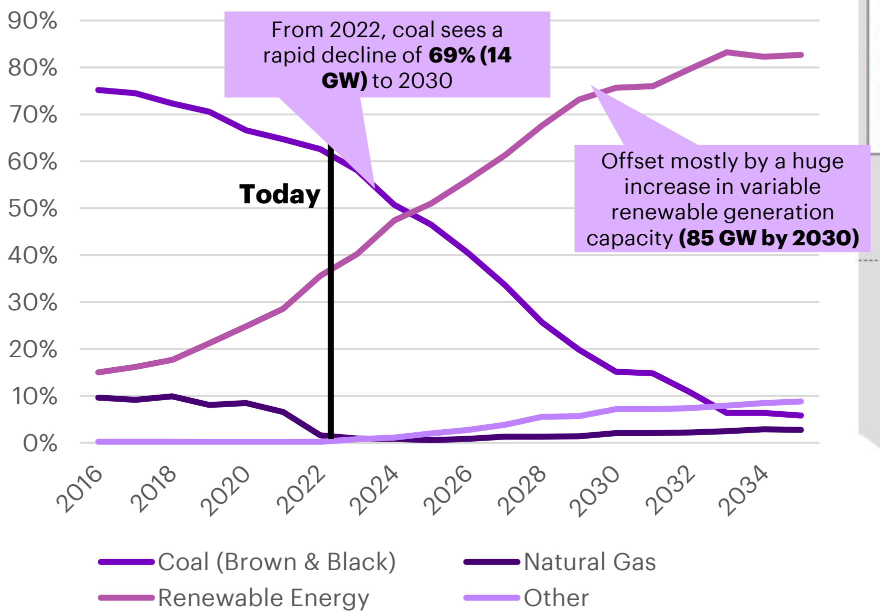
The AEMO Integrated System Plan (ISP) is a detailed publication providing a **‘whole of system’ plan**, offering a roadmap for developing Australia’s eastern electricity system. This plan focuses on supply-side interventions that will transform the Australian Energy Mix away from coal. The interventions include:

1. The establishment of Renewable Energy Zones (see Fig 1)
2. Build-out of transmission network connecting to those Renewable Energy Zones (see Fig 1)
3. Increase in renewable generation from **45%** of capacity in 2020 to **86%** in 2030
4. Total generation volume increasing by **50%** between 2021 and 2035

For this to be achieved, by 2050, the NEM will need approximately:

- 46 GW of dispatchable storage, 7 GW of hydro-generation (e.g. Snowy Hydro) & 10 GW of gas-fired generation for peak loads and firming
- 10 000 km of new transmission lines to renewable energy zones

Australian Energy Generation Mix (%) 2016 to 2035



In addition to the ISP, market changes are accelerating Australia’s journey away from coal as stations close earlier than planned. For example the expedited **phase out of the coal-fired Loy Yang A Power Station**, Australia’s largest carbon-polluting plant, which currently provides 30% of Victoria’s electricity, being brought forward from 2045 to 2035.[1]

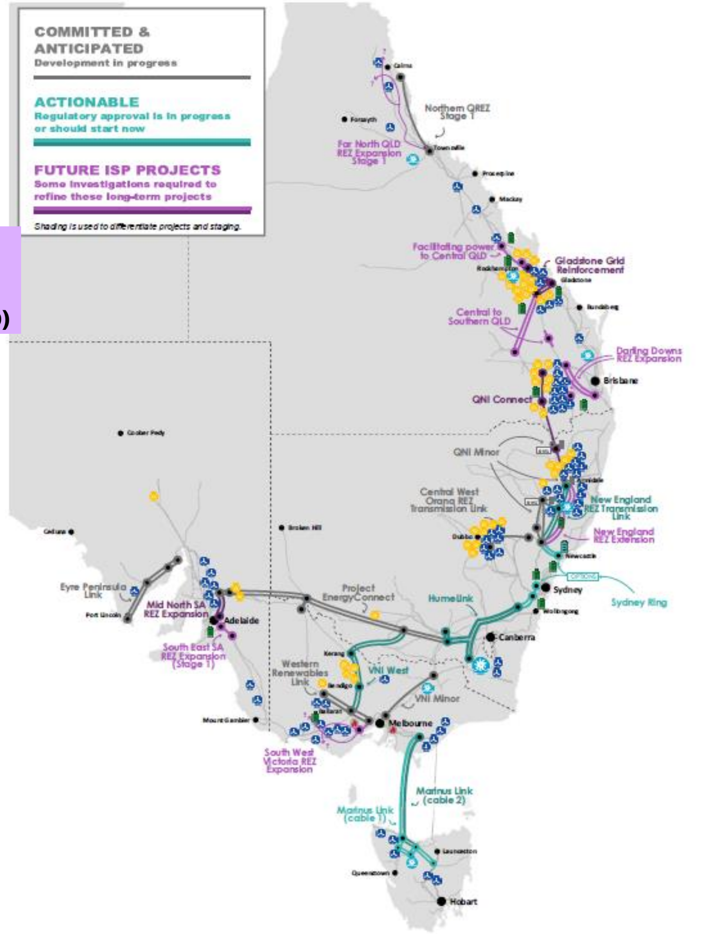


Figure 1: Map of the Network Investments in the Optimal Development Path, [2022 Integrated System Plan](), AEMO (June 2022).

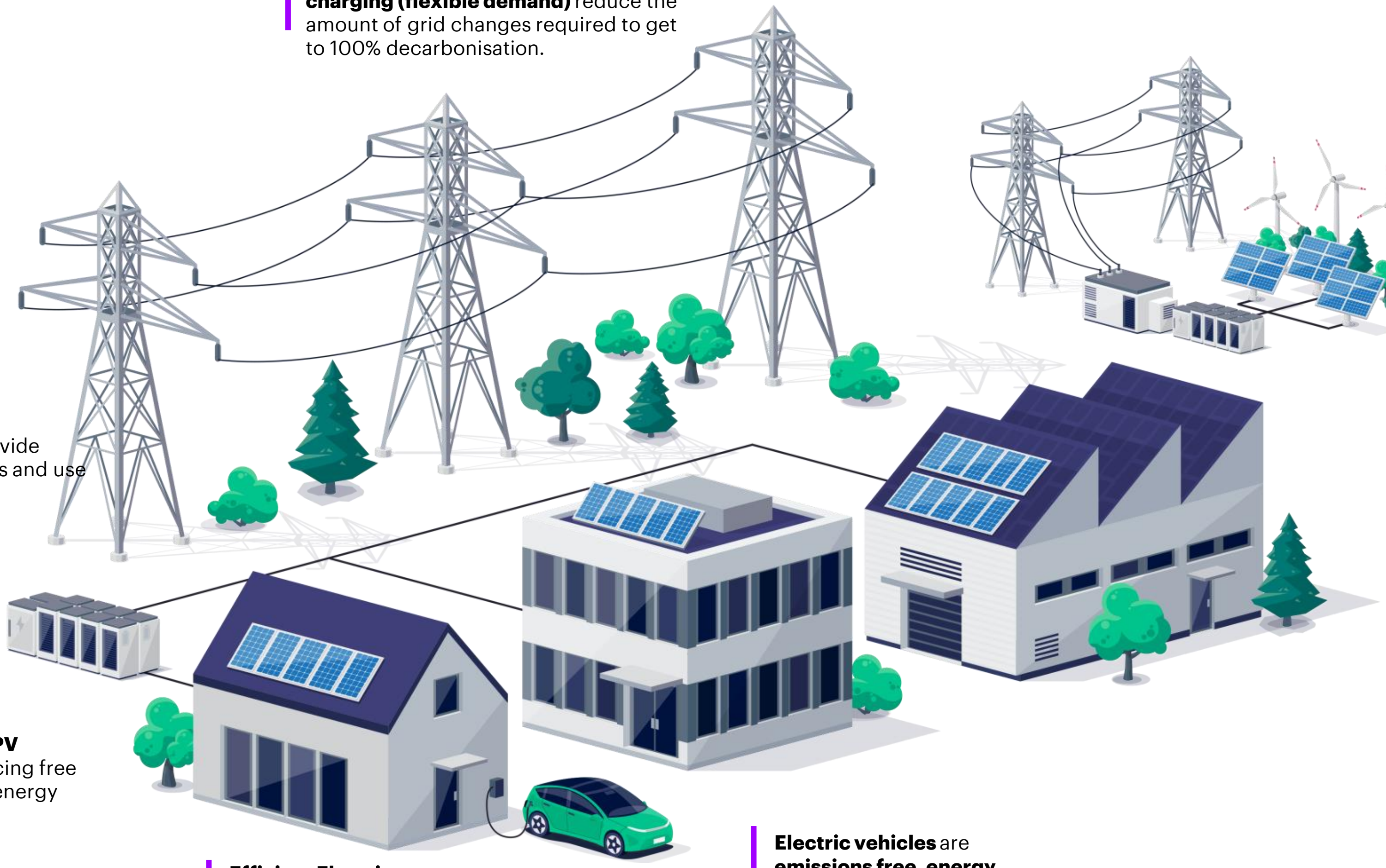
1. Source: [AGL, How We Source Energy: Loy Yang Power Station]()

We also need to address how we use energy – the demand side

How we live, move and work is inextricably linked to how we use energy. Changing this "demand side" of the energy equation requires a societal transformation but will benefit all Australians and make the supply side changes more efficient and cost-effective

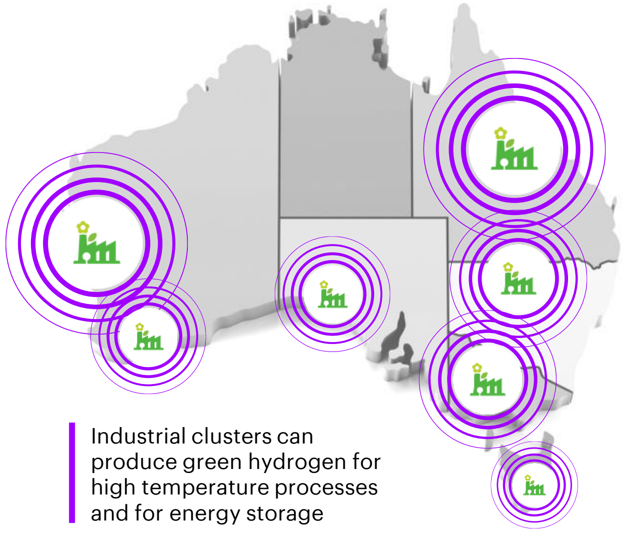
Smart appliances and **smart EV charging (flexible demand)** reduce the amount of grid changes required to get to 100% decarbonisation.

Electricity in low temperature industrial processes **is more efficient** than burning fossil fuels



Geographically co-located 'clusters' of industry can **create regional jobs**, soak up excess renewables production and 'share' resources more efficiently

Home batteries provide resilience to outages and use up excess solar



Solar PV producing free clean energy

Efficient Electric appliances reduce our energy usage

Electric vehicles are **emissions free, energy efficient** and **quiet**

Industrial clusters can produce green hydrogen for high temperature processes and for energy storage

Our selected demand side interventions bring the benefits of the energy transition to Australians, changing how we live, move and work

Encourage Residential and Commercial Self-Consumption

Rapidly scale up Australia's Distributed Energy Resources and batteries. Solar panel deployment on the residential and commercial levels is incentivised, and solar self-consumption is encouraged through community batteries, demand response, home batteries, etc.

- **42 MMT** Cumulative CO2 emissions reduction between 2022-35
- **54 Bn L** Cumulative water consumption reduction
- **3.1 hour** Emergency electricity supply in 2035

Accelerate Electric Vehicle Adoption

Aggressively accelerate the deployment of electric vehicles. This may be achieved through policy means such as banning the sale of ICEs after a specific date, reduced registration costs, direct subsidies at the point of sale, free or discounted parking and toll roads, etc.

- **69 MMT** Cumulative CO2 emissions reductions between 2022-2035
- **158 Bn L** Cumulative water consumption reduction
- **15%** Reduction in energy per unit cost in 2035
- **9,046 ML** Fuel saved in 2035

Electrify and Transform Residential and Commercial Energy Demand

Support fuel switching from gas to electricity in homes and commercial buildings. In residential areas, houses are enabled to be built without gas connections. Gas stoves and heaters are replaced with electric appliances.

- **53 MMT** Cumulative CO2 emissions reduction between 2022-35
- **>111K** Clean energy jobs between 2022-35
- **$21 bn[1]** Cumulative health cost savings between 2022-35

Electrify Industries and Establish Industrial Clusters

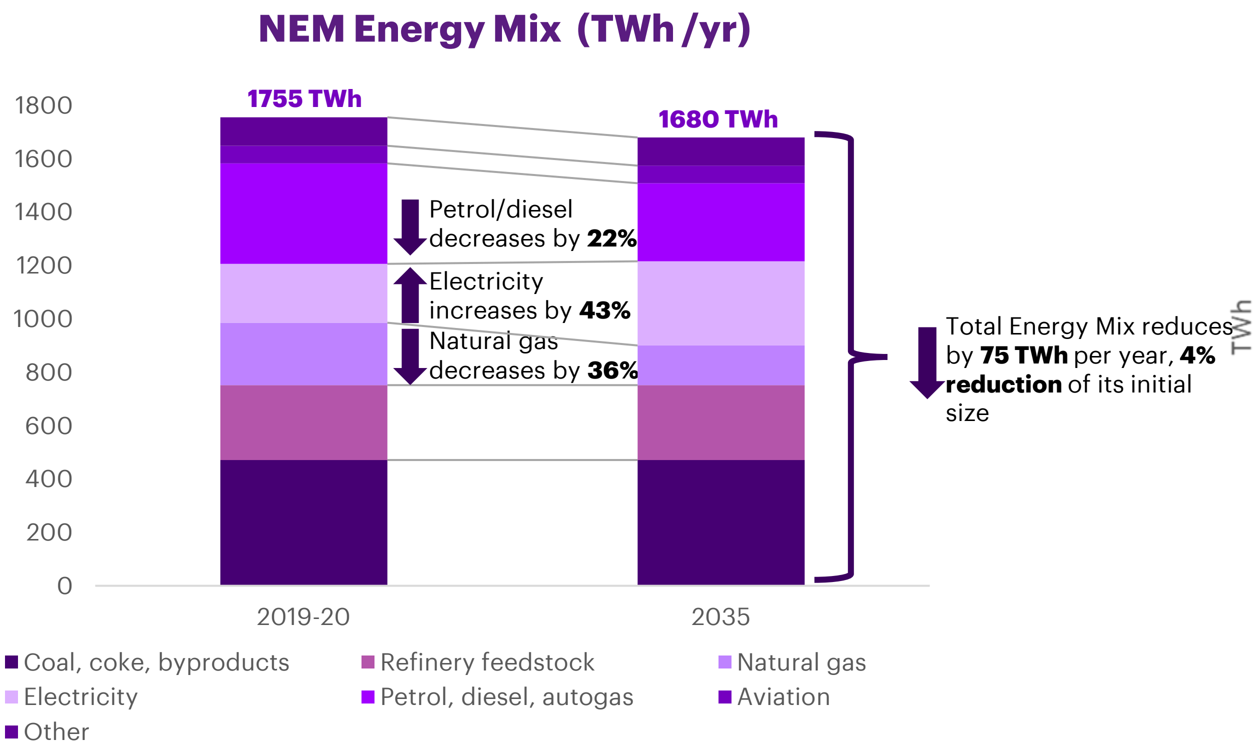
Rapidly switch industry from fossil fuels to using electricity. Partially this takes place in existing industrial locations, however it also involves the enabling and incentivising of decentralised industrial clusters and REZs with ready access to renewable energy and the ability to share resources with other co-located industries.

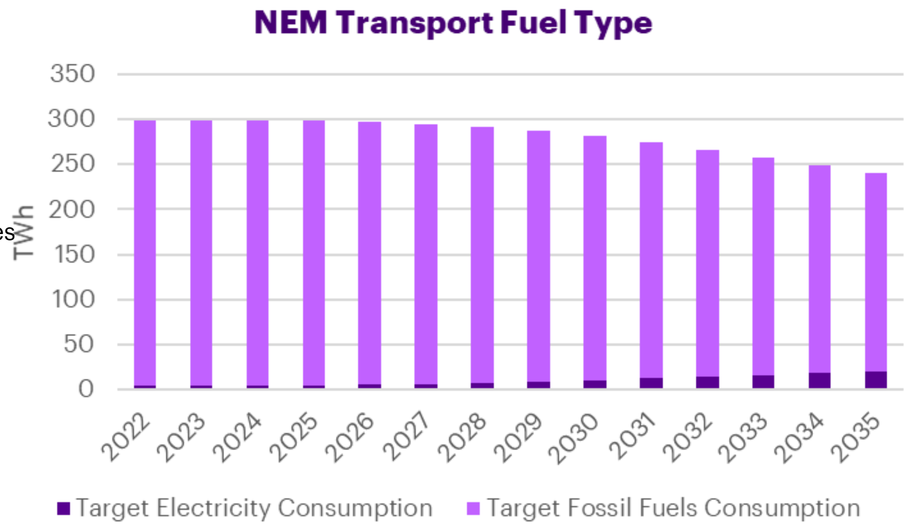
- **285 MMT** Cumulative CO2 emissions reduction between 2022-35
- **11%** Reduction in energy per unit cost in 2035
- **58 TWh** Additional flexible generation in 2035
- **$ 5.1 Bn[1]** Cumulative health cost savings between 2022-35

[1]Cumulative health savings are calculated based on avoided medical costs associated with particulate, sulphur dioxide and nitrous oxide, emissions (impact on respiratory health) and noise pollution. The primary health benefit arises from removing gas appliances from Australian households.

These interventions change the energy mix and reduce the total use of energy through increased energy conversion efficiencies

Shifting to electrification across the demand side reduces national primary energy input into the energy system since electrification is more efficient – we model a 4% reduction in energy usage overall





The increased electricity efficiency over other fuels will reduce the NEM Energy Mix by 4%, compounding all other benefits of decarbonisation and reducing costs.

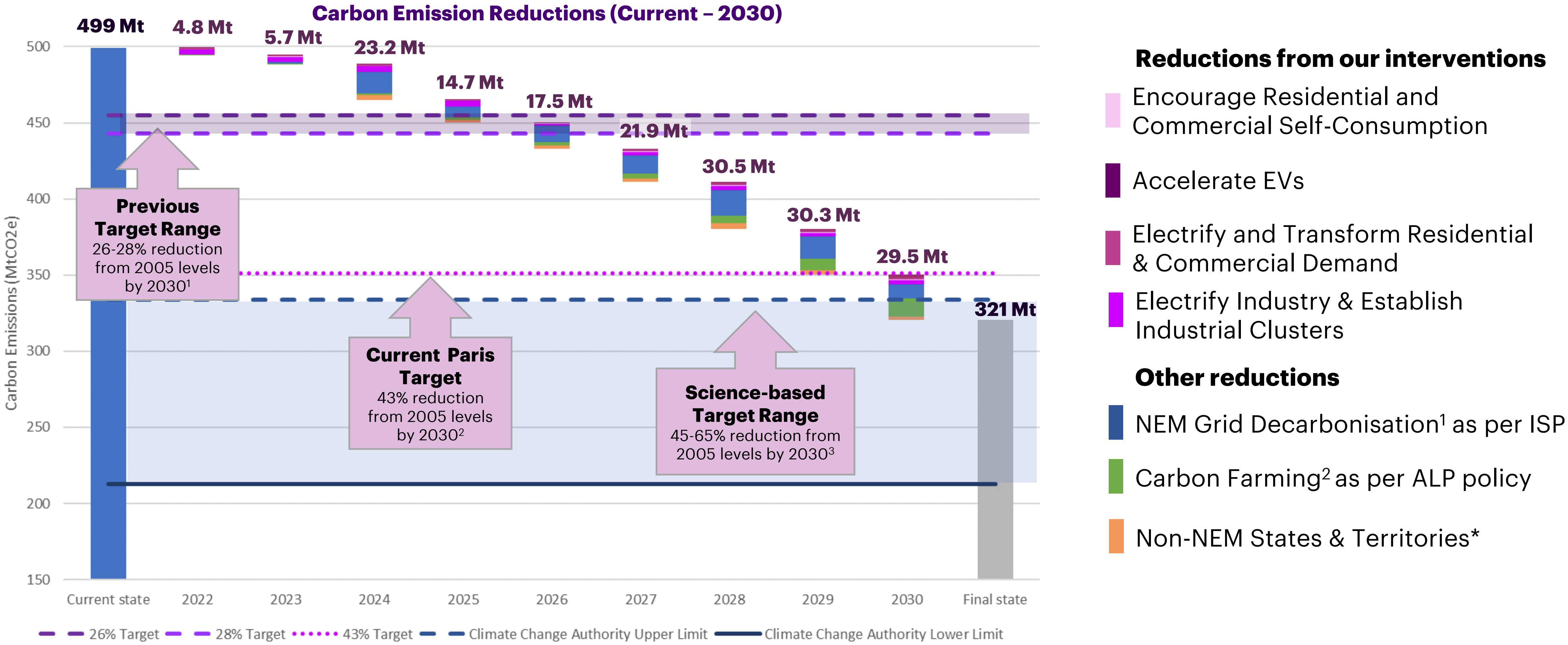
Electric vehicles are significantly more efficient than petrol and diesel. Switching to electric vehicles, therefore, reduces Australia's overall transport energy usage by 20%.

Source: Australian Energy Statistics, Table F1, Department of Industry

*This chart assumes that the energy mix in 2022 is the same as that of 2019-20 (the most recent available data).

To meet 2030 emissions targets, demand-side interventions need to be complemented by the acceleration of grid decarbonisation

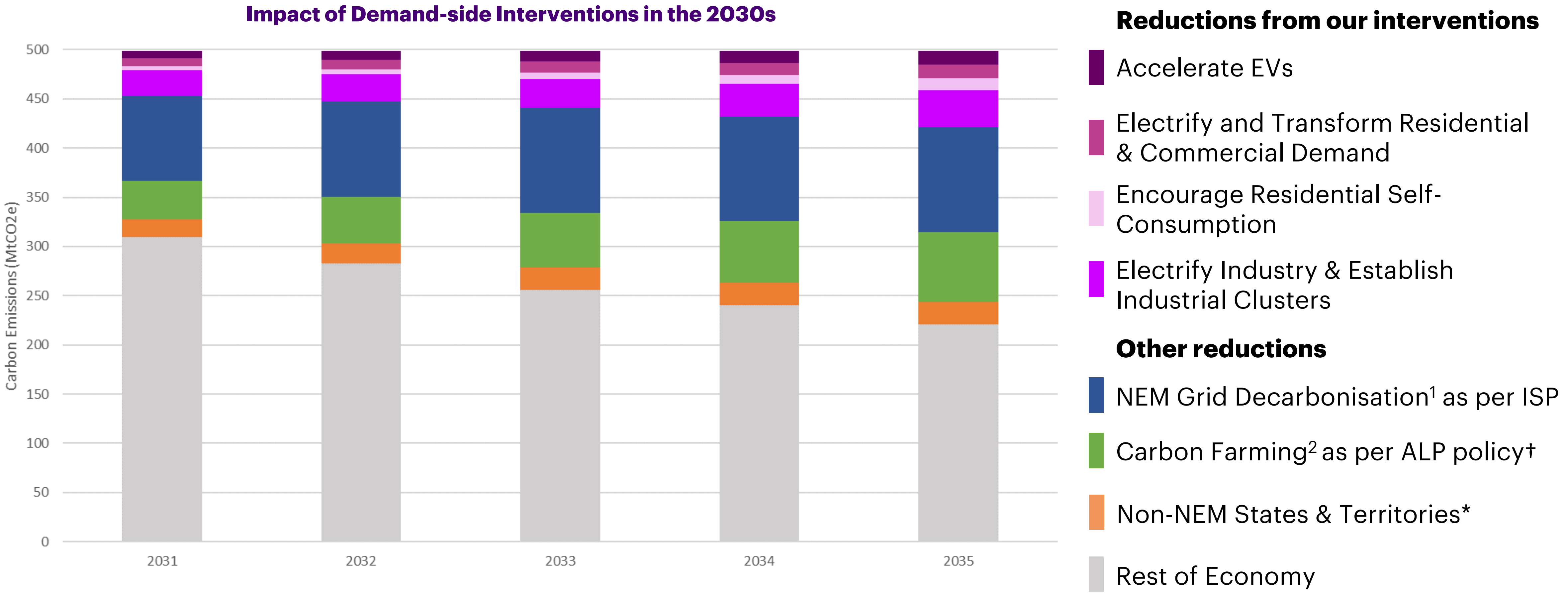
Achieving Australia's new Paris target of 43% reduction of 2005 levels by 2030 can be assisted through these demand-side interventions, leading to Australia beating the 43% target



Source: 1 Australia's emissions projections 2022 (November 2022) *Department of Industry, Science, Energy and Resources* 2. Powering Australia Plan (2021), Australian Labor Party 3. Final report on Australia's future emissions reduction target (2 July 2015), Australian Government Climate Change Authority.
* Assumes that other states and territories decarbonise their grids at a similar rate to the NEM.

Demand-side interventions become much more impactful in the decade following 2030 (i.e., for a 2035 or 2050 emissions target)

More importantly, the demand-side interventions start to substantively accrue in the 2030's, reducing Australia's emissions by an additional ~72 Mt CO_2e per year by 2035



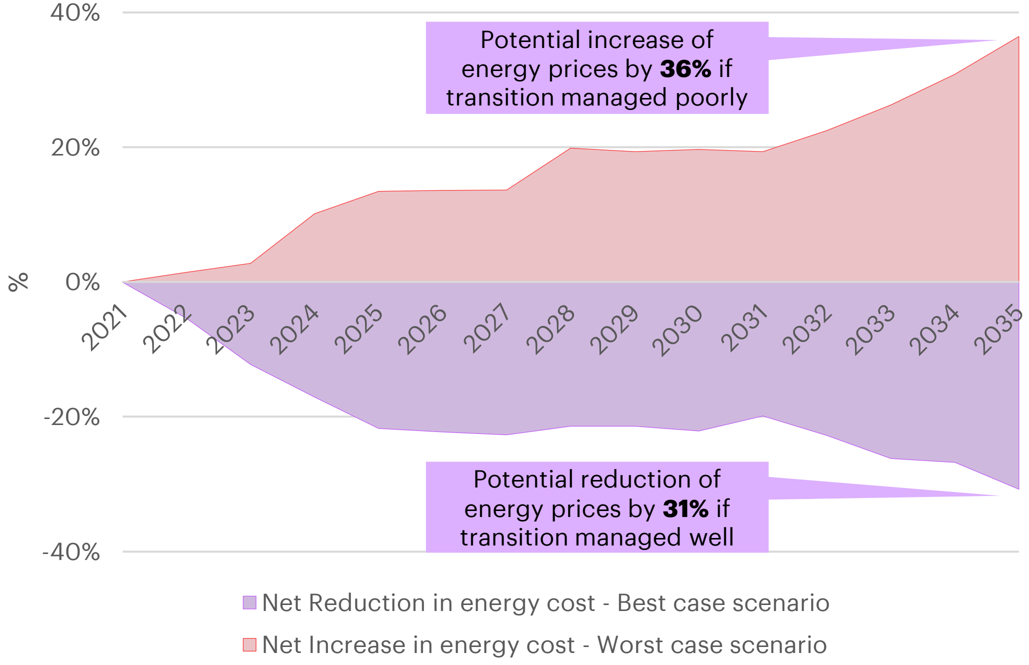
Source: 1 Australia's emissions projections 2022 (November 2022) *Department of Industry, Science, Energy and Resources* 2 ALP'S Powering Australia Plan.
* Assumes that other states and territories decarbonise their grids at a similar rate to the NEM.
† Assumes that carbon farming initiative will continue at a consistent rate after 2030.

The interventions reduce energy prices for ALL Australians, whether they have bought new energy products or not

Access to Electricity
Physical and economic access to clean electricity to support individual or society development

Electricity prices go down due to more efficient utilisation of network and generation assets (fixed costs spread over a larger base)

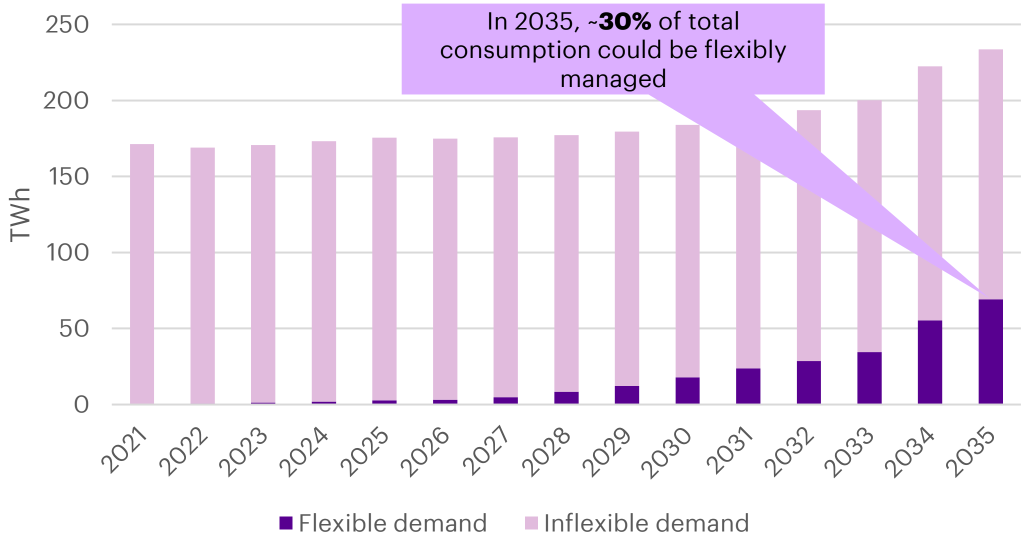
Electricity Price Changes



Flexibility
Ability to manage generation, demand and power flows (incl. power quality) across the grid, enabled by digitalisation and storage

Increased dispatchable demand that can be controlled by distributors and generators to balance supply and demand and protect grid assets, enabling the last 20% of decarbonisation to be done at least cost

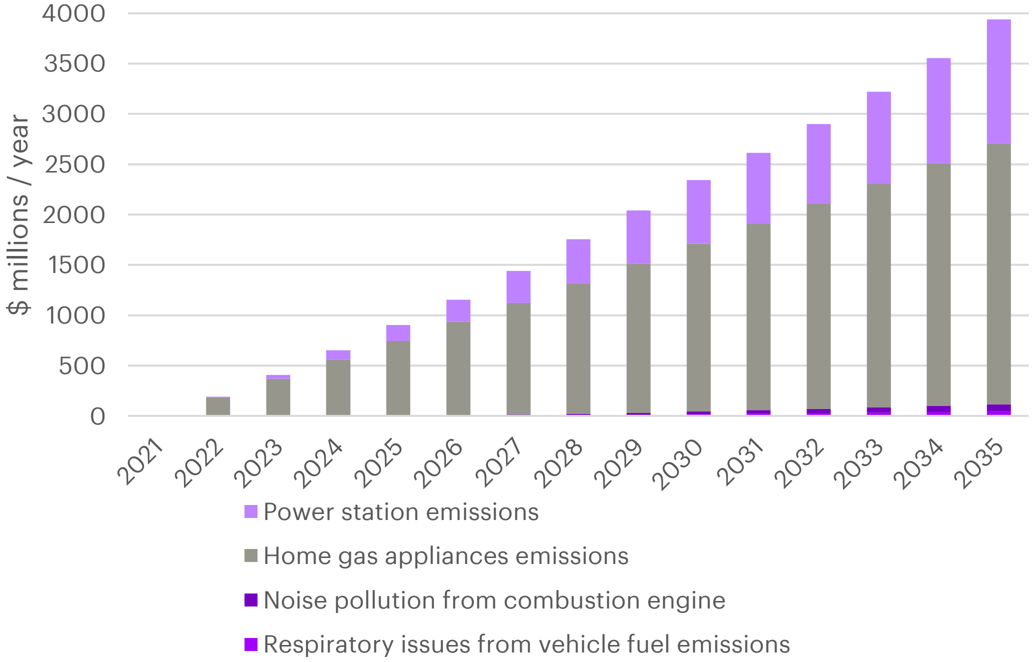
Electricity demand



Hidden health costs of the current status quo are relieved, providing bottom line budget savings of nearly $4b per year in 2035

Reduction in harmful pollutants (PM10, PM2.5, NO_x, SO_2) and in noise pollution. This improves respiratory health (incl. asthma) and mental / physical health through reduced stress.

Avoided Healthcare Costs[1] (Savings)



[1]Avoided Healthcare Costs reflect saved "bottom-line' medical costs associated with these interventions (e.g., reduction in hospital costs associated with pollution-related respiratory illness).

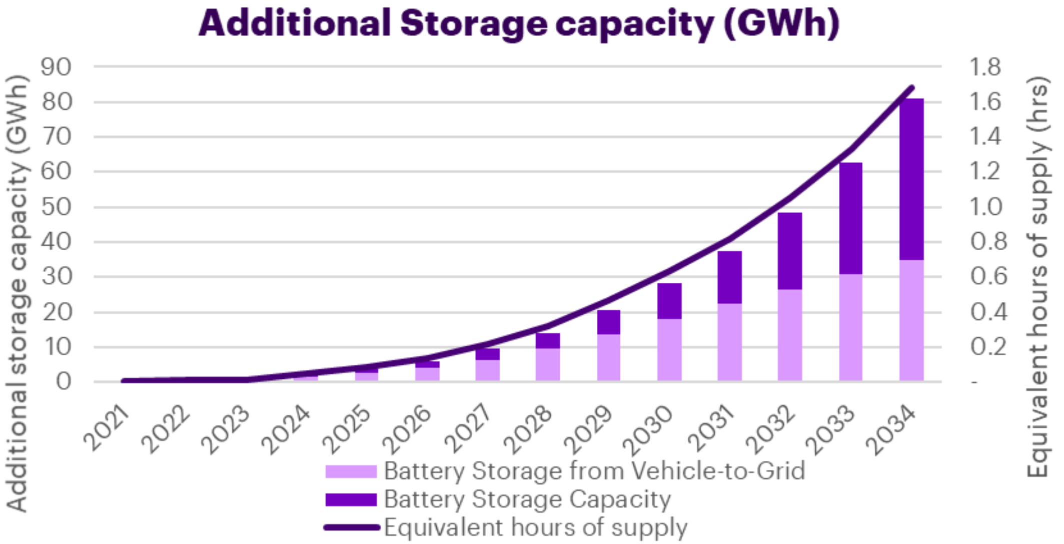
If additional measures such as the economic output of longer life expectancy and improved quality of life (the 'value of a statistical life' of $222K per life-year) are included, this benefit increases **by an order of magnitude.**

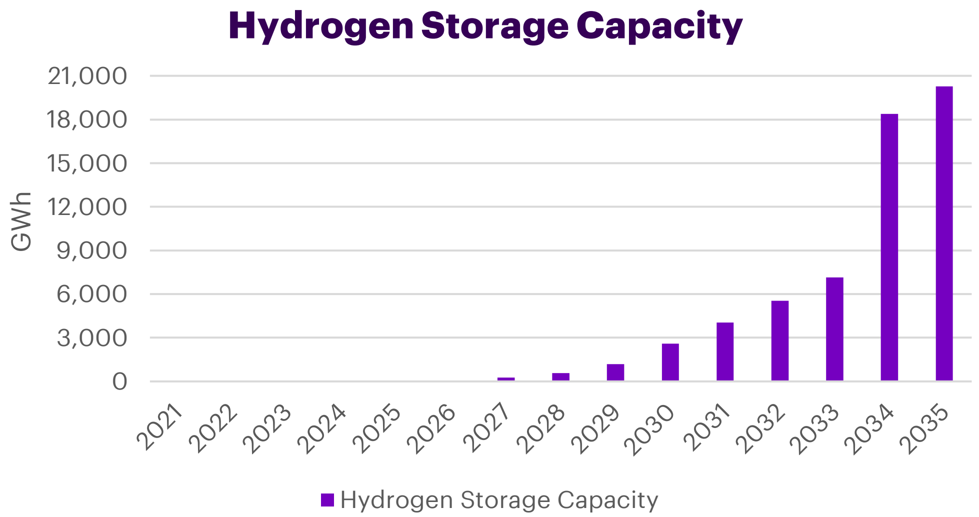
Interventions can also improve individual and national energy resilience to natural disasters and external security threats

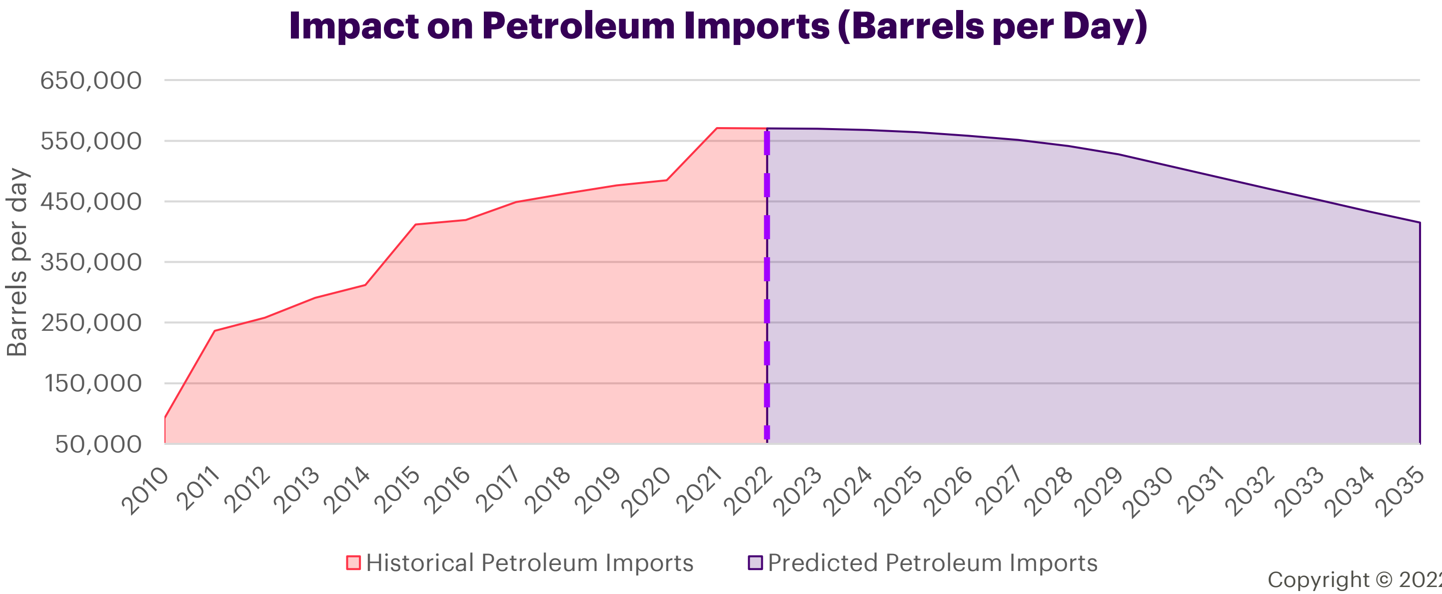
Resiliency and Security

Uninterrupted and diversified energy supply at affordable prices and the ability to bounce back from disruptions

Additional storage capacity from vehicle-to-grid, added battery storage capacity and from hydrogen. Less demand on combustion engine car will reduce the demand for petroleum import



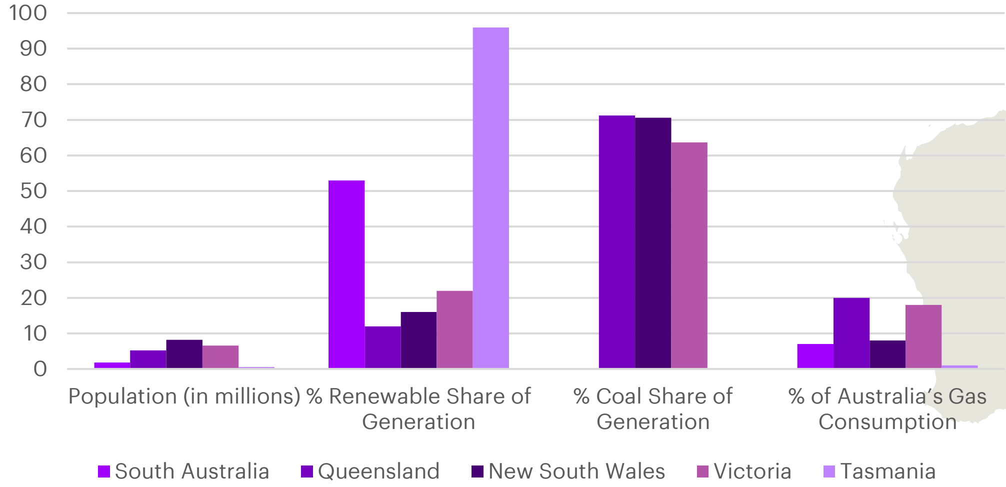


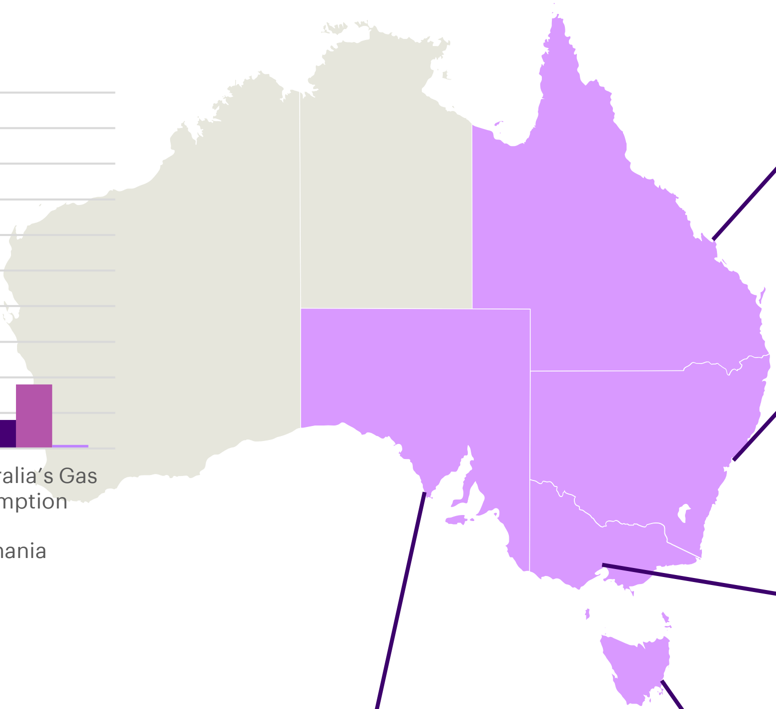


National Energy Market States

Australia, and each state and territory in Australia, has a Net Zero by 2050 target, but the short-term federal target is a 43% reduction by 2030 (from a 2005 baseline)

State-wise Generation and Consumption Data





Queensland

Renewable Energy Target: 50% by 2030
Emissions Reduction Target: 30% by 2030

New South Wales

Renewable Energy Target: 50% by 2030
Emissions Reduction Target: None

Victoria

Renewable Energy Target: 50% by 2030
Emissions Reduction Target: 28-33% by 2025 and 45-50% by 2030

NEM States & Territories

Population: 22.8 million (88% of total)

Total Energy Consumption: 4594 PJ/year (76% of total)

Electricity Consumption:
217 TWh/year (82% of total)

South Australia

Renewable Energy Target: 100% by 2030 and 500% by 2050
Emissions Reduction Target: 50% by 2030

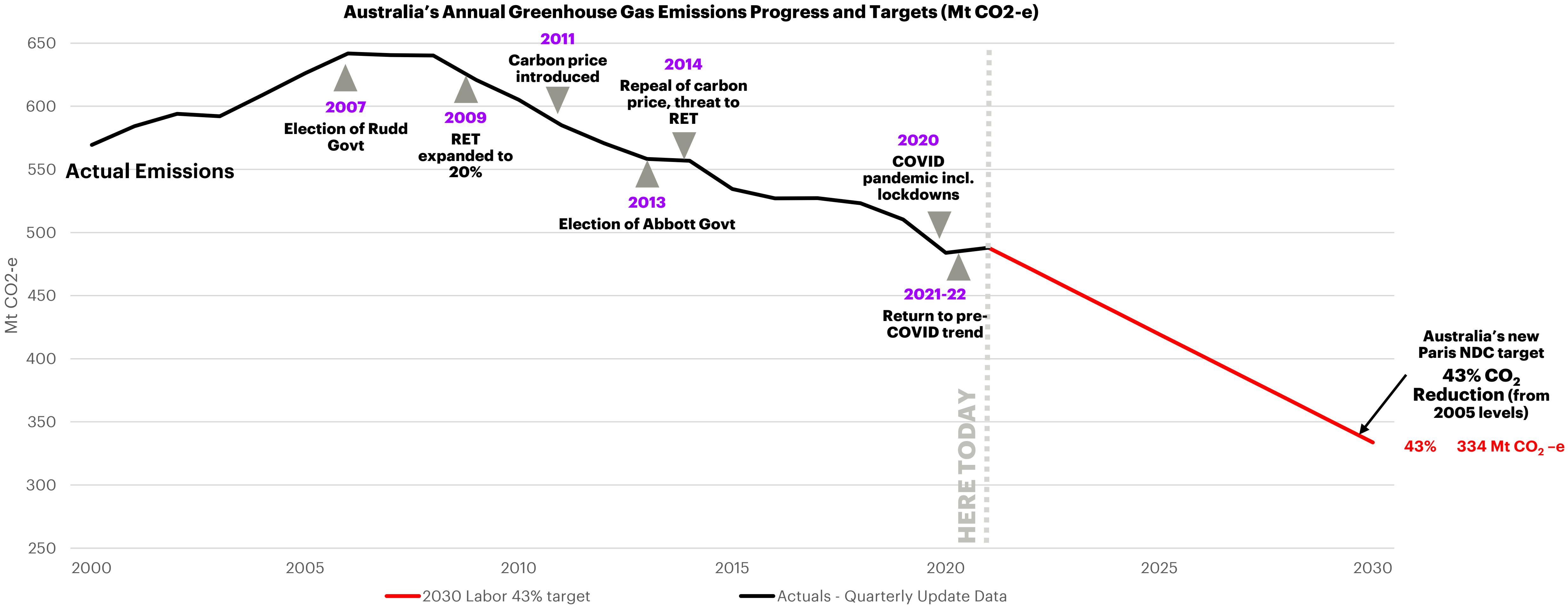
Tasmania

Renewable Energy Target: 100% by 2022 and 200% by 2040
Emissions Reduction Target: Net zero by 2050

Source: Australian Energy Statistics, DISER, Table C total primary energy source (2019-20), Australian Energy Statistics, DISER, Table F Total by fuel type (2019-20, Accenture analysis, National Greenhouse Gas Inventory Quarterly Update (December 2020), Energy Policies of IEA Countries - Australia 2018 Review

Australia’s Carbon Emissions – Progress, Trajectory and Targets

The temporary reductions in emissions due to the Covid pandemic have come back to trend, and this trend will require rapid change to meet Australia’s new Paris target of a 43% reduction against 2005 levels (let alone a more ambitious target)

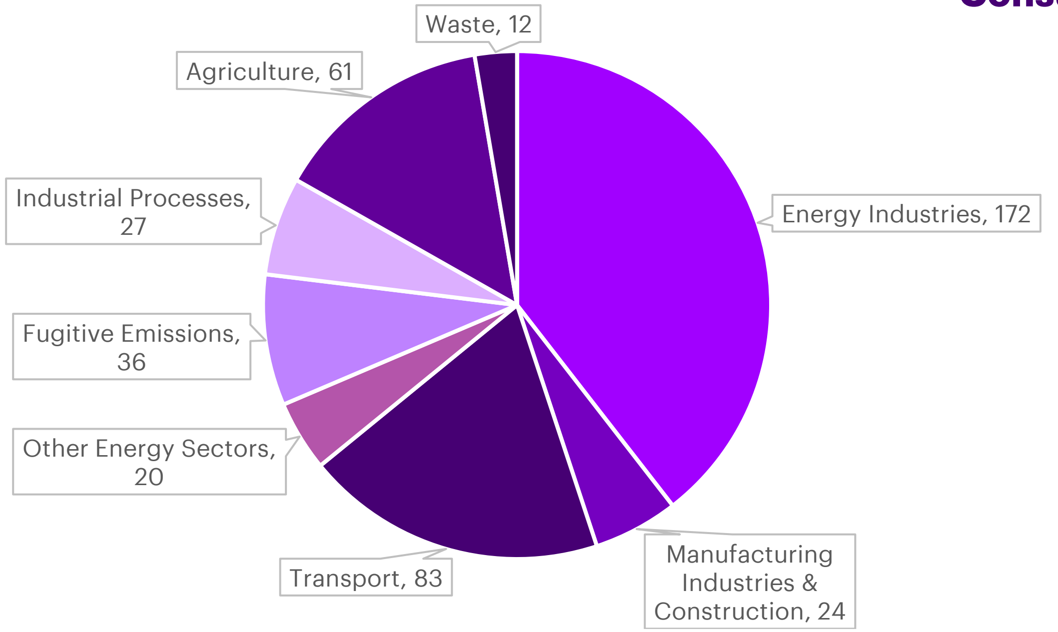


Source: Quarterly Update of Australia’s National Greenhouse Gas Inventory: June 2022. *Department of Industry, Science, Energy and Resources,* Australia’s emissions projections 2021, October 2021. *Department of Industry, Science, Energy and Resources*

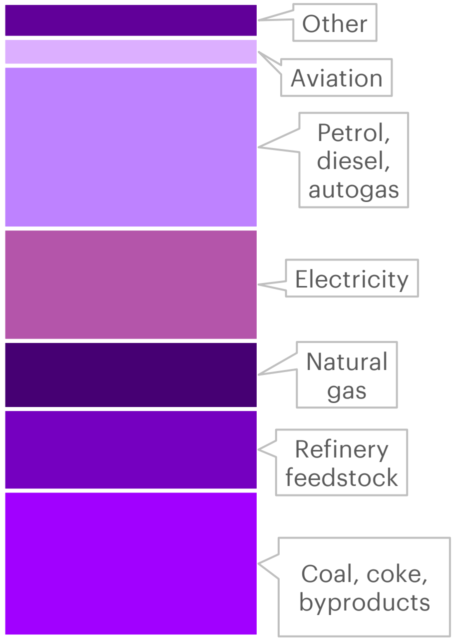
NEM Energy Mix and Carbon Emissions

Electricity generation is the largest contributor to the NEM's greenhouse gas emissions.[1] Electricity generation in the NEM alone is responsible for 27% of Australia's total emissions. However, industry and transport are also significant contributors. Overall, fossil fuels accounted for 93% of Australia's primary energy mix in 2019-20. The Energy Mix[2] reveals opportunities for fuel switching and efficiency improvements

NEM Emissions by Category (Mt CO_2e)



Current NEM Energy Consumption by Fuel Type (2019-20)



1276 NEM states and territories' energy consumption is approximately 1276 TWh – roughly three quarters of Australia's total energy consumption

72% 72% of NEM states and territories' emissions come from the combustion of fossil fuels

41% 41% of NEM states and territories' emissions come from Energy industries (mostly electricity generation)

20% Transport is the NEM state & territories' second-biggest source of emissions at 20% of total

2040 AEMO predicts that all coal power plants could shut as soon as 2040[3]

Source: 1. [Quarterly Update of Australia's National Greenhouse Gas Inventory: June 2021] (December 2021). *Department of Industry, Science, Energy and Resources* 2. [Table F: Australian energy consumption, by state and territory, by industry and fuel type, energy units], Australian Energy Statistics (2022).3. [2022 Integrated System Plan], AEMO (June 2022).

Overview of Australia's Electricity Market

In 2020, 27% of Australia's electricity came from renewable energy sources. It is rapidly decarbonising such that it is estimated that renewables will constitute 49% of renewable generation, and 63% of capacity by 2030[1]

Structural components of Australia's market

- The NEM is both a wholesale electricity market and the physical power system.
- It covers approx. 40,000km of transmission lines and cables.
- Retail electricity markets underpin the wholesale market.
- Australia-wide, more than 30% of households have solar panels. Householders can sell electricity to the grid through feed-in tariff schemes.

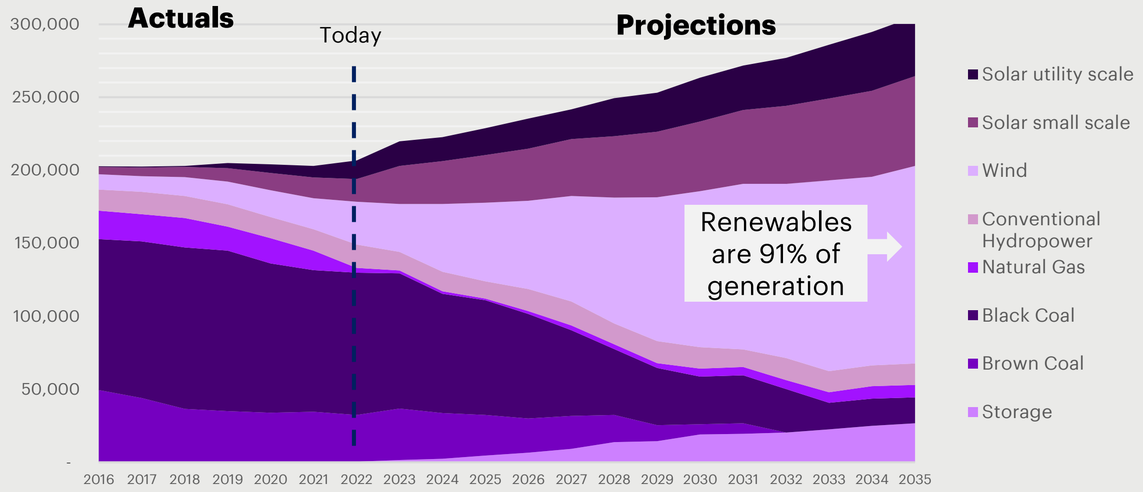
Diversifying generation

- Renewable generation is predicted to triple by 2030 as total renewable capacity increases to 92 GW, driven by projected 34 GW of added small and utility scale solar and 23 GW onshore wind.[1]
- Distributed generation is projected to increase dramatically in the 2020s.
- Thermal coal generates the most energy in the NEM and Victoria, however is projected to decrease by 15 GW by 2035 with the closure of coal power stations.
- Natural gas generation is projected to decrease in the 2020s, but to increase in the 2030s.

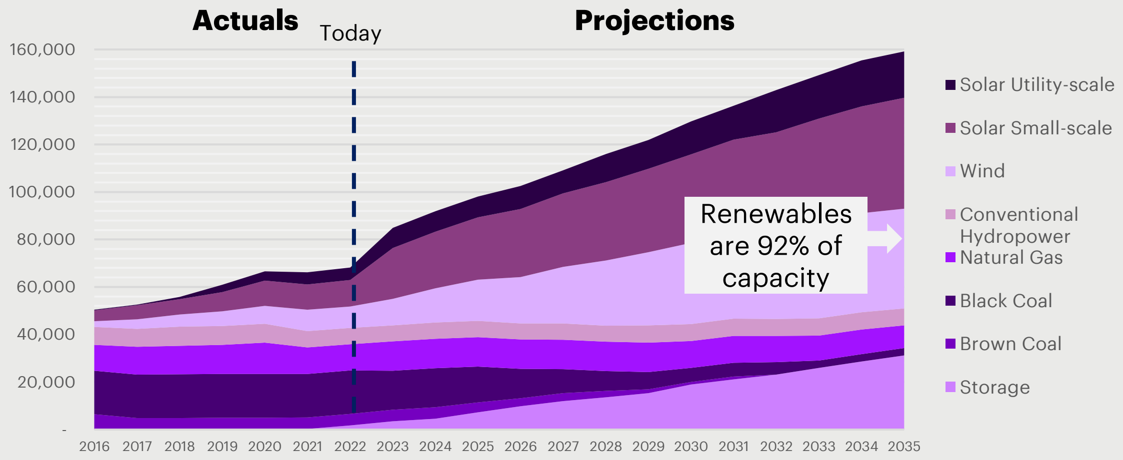
Renewable energy goals

- Australia has committed to net zero by 2050 through the *Climate Change Bill 2022*, bolstered by pre-existing legislation from all states and territories committing to this goal.
- The bill has an additional target of a 43% reduction on 2005 levels by 2030. This will require emissions to lower a further 28% from current emissions from 487 Mt CO_2-e to an end target of 351 Mt $CO2\text{-}_e$[2]

Electricity Generation Breakdown NEM to 2035 (GWh)[1]



Capacity Breakdown NEM to 2035 (MW)[1]



Source: 1. [2022 Integrated System Plan](), AEMO (June 2022). *For details of the ISP, see the appendix.* 2. [Quarterly Update of Australia's National Greenhouse Gas Inventory: March 2022](), DCCEW

AEMO 2022 ISP – Renewable Energy Zones

Renewable Energy Zones (REZ) are identified zones with high availability of variable renewable energy (VRE) resources such as solar, wind and storage. Developing transmission line access to these regions will unlock those resources and provide certainty to developers. Transmission companies and governments will be mostly responsible for the connectivity to these zones, and then generators will be responsible to build VRE plants

The AEMO ISP Step Change scenario includes the following specific interventions:

- Establishment of **Renewable Energy Zones**
- Build-out of transmission network connecting to those Renewable Energy Zones

15GW

Currently there is approximately 15GW of utility scale VRE in the NEM

5.1GW

Another 5.1GW is expected to be operational over the next two years

34-47GW

To ensure strong growth in DER, Australia will need an additional 34 to 47GW of new VRE

The AEMO ISP forecasts that **VRE capacity** will increase to **140GW** by 2050 in the Step Change Scenario which is equivalent to over a doubling of capacity every decade. **Distributed PV** is forecast to increase **from 15GW to nearly 70GW** in the same period.

Solar and wind VRE are both required to be able to transform the NEM efficiently, as they offer complementary daily and seasonal profiles. Alongside distributed PV, wind and solar will have almost equal shares of NEM generation by 2050.

In the **Step Change,** the following development in the NEM regions is projected to what is already existing, committed or anticipated in the next **10-20 years:**

NSW	QLD	SA	TAS	VIC
38GW new VRE by 2050	47GW new VRE by 2050	15GW new VRE by 2050	2.5GW new wind by 2050	23GW new VRE by 2050

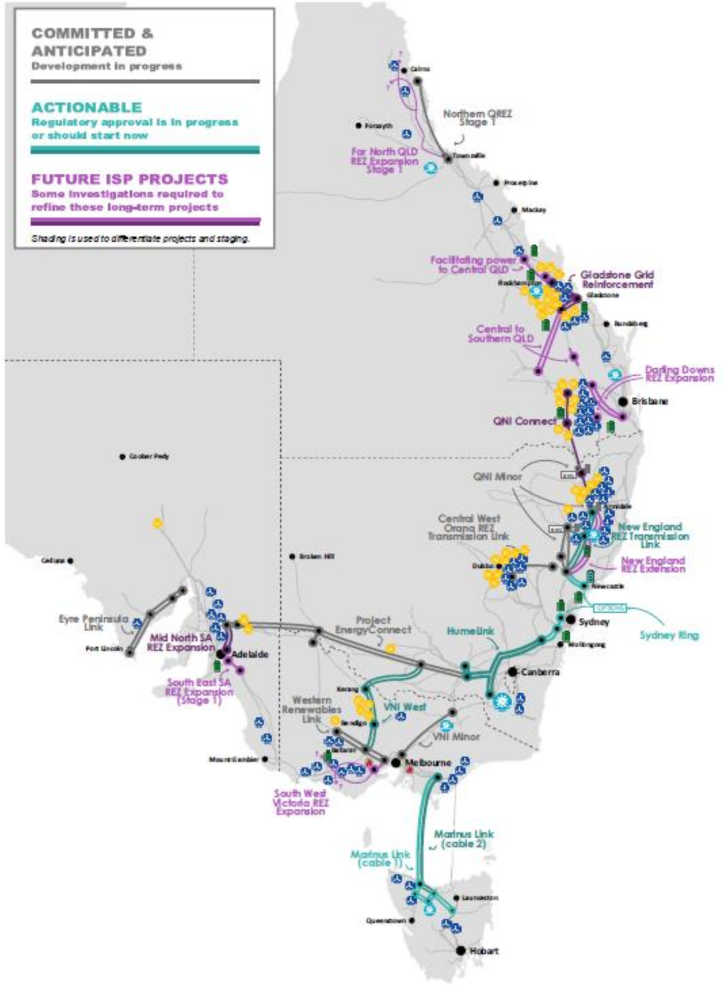


Figure 1: Map of the Network Investments in the Optimal Development Path, 2022 Integrated System Plan, AEMO (June 2022).

Source: Appendix 3. Renewable Energy Zones - Appendix to 2022 ISP, *AEMO* (December 2021), 2022 Integrated System Plan, AEMO (June 2022)..

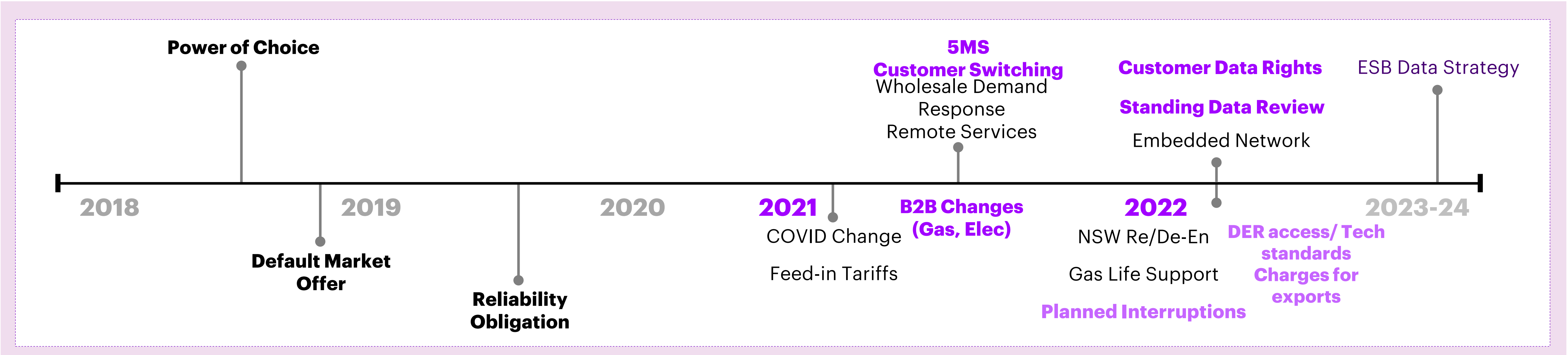
Note: See the appendix for more on the ISP and the development pathways.

Australia Market Reforms In Train

- **In 2021 / 2022 the 'big ticket items' were:**
  - **5 Minute Settlement (1 Oct)**
  - **Customer Switching (1 Oct)**
  - **Wholesale Demand Response (24 Oct)**
  - **B2B Changes (10 Nov, 29 Nov)**
  - **Global Settlement (1 May)**

- **Looking ahead in 2022 - 23**
  - **Standing Data Review (1 May, & 1 Oct)**
  - **Customer Data Rights for Utilities (Oct)**
  - **DER access and standards**
  - **Solar export charges**

- **Looking ahead to 2024-2025**
  - **DER Marketplace**
  - **Enablement of REZ's**
  - **Post 2025 Market Reform**



Key Question

How can Australia build a future-proof and resilient energy system while capitalising on its abundant renewable energy resources?

Interventions for Australia

This analysis explores four possible opportunities for intervention in Australia's electricity system. To respond to the need for demand-side changes, these are interventions that operate independently from supply-side transformation

	Intervention	Description
1	**Encourage Residential and Commercial Self-Consumption**	The Residential and Commercial Self-Consumption intervention rapidly scales up Australia's Distributed Energy Resources and batteries. Solar panel deployment on the residential and commercial level is incentivised, and the self-consumption of solar is encouraged through community batteries, demand response, home batteries, etc.
2	**Accelerate Electric Vehicle Adoption**	The Accelerate EV Adoption intervention aggressively accelerates the deployment of electric vehicles. This may be achieved through policy means such as banning the sale of ICEs after a certain date, reduced registration costs, direct subsidies at point of sale, free or discounting parking and toll roads, etc.
3	**Electrify and Transform Residential and Commercial Energy Demand**	The Electrify & Transform Residential and Commercial Energy Demand intervention supports fuel switching from gas to electricity in homes and commercial buildings. In residential areas, houses are enabled to be built without gas connections. Gas stoves and heaters are replaced with electric appliances.
4	**Electrify Industries and Establish Industrial Clusters**	This intervention rapidly switches industry from using fossil fuels to using electricity. Partially this takes place in existing industrial locations, but it also involves the enabling and incentivising of decentralised industrial clusters with ready access to renewable energy and the ability to share resources with other co-located industries.

System Value of clean energy transition

System Value benefits are seen across Australia's recovery solutions

Economic, environmental, societal and energy value

	CO_2 Emissions CO_2 emissions based on energy source, generation mix and load changes	**Water Footprint** Water footprint based on energy source, generation mix and load changes	**Access to Electricity** Physical and economic access to clean electricity to support individual or society development	**Jobs and Economic Impact** Influx of jobs due to energy transition and renewables	**Air Quality and Health** Impacts to human health and natural environment from air & water pollutants, land use	**Resiliency and Security** Uninterrupted and diversified energy supply at affordable prices and the ability to bounce back from disruptions	**Energy Productivity and Systemic Efficiency** Energy efficiency plus systemic efficiency to maximise energy productivity	**Foreign Direct Investment** Market attractiveness for FDI with reliable energy and skilled resources	**Reliability and Service Quality** Life cycle approach to ensuring high system availability; improved customer service	**Flexibility** Ability to manage generation, demand and power flows (incl. power quality) across the grid, enabled by digitalisation and storage	**System Upgrade** Technology (incl. digital) and capital investments in T&D to upgrade the system for variable renewables and DERs	**Cost and Investment Competitiveness** Market attractiveness and policy certainty for investment incl. R&D and levelised cost of energy
1. Encourage Residential and Commercial Self Consumption	13 Mt/ yr saving	16 Bn L / yr saving	●	◐	$0.3 Bn /yr saving	3.1 hours of NEM supply	●		◐	10 GWh	○	○
2. Accelerate Electric Vehicle Adoption	14 Mt / yr saving	32 Bn L / yr saving	Up to 15% price savings	◐	$0.1 Bn / yr saving	9,000 ML avoided fuel imports 0.7 hours of NEM supply	●		○	5.3 TWh (3.4% of total load)	◐	●
3. Electrify and Transform Residential and Commercial Energy Demand	8 Mt / yr saving	15 Bn L / yr saving	Up to 5% price savings	●	$3 Bn / yr saving	◐	◐		◐	835 GWh (1% of total load)	◐	○
4. Electrification of Industries and Establish Industrial Clusters	37 Mt /yr saving	28 Bn L / yr increase (required for hydrogen production)	Up to 11% price savings	●	$0.8 Bn / yr saving	◐	●		●	58 TWh (27% of total load)	○	●

Savings given as per year figures in 2035

Relative System Value dimension benefit for given recovery solution within market: ● High benefit ◐ Medium benefit ○ Minimal-to-no benefit

1. Encourage Residential and Commercial Self-Consumption

Small-scale solar and batteries to increase flexibility and resilience in homes and commercial businesses

Overview

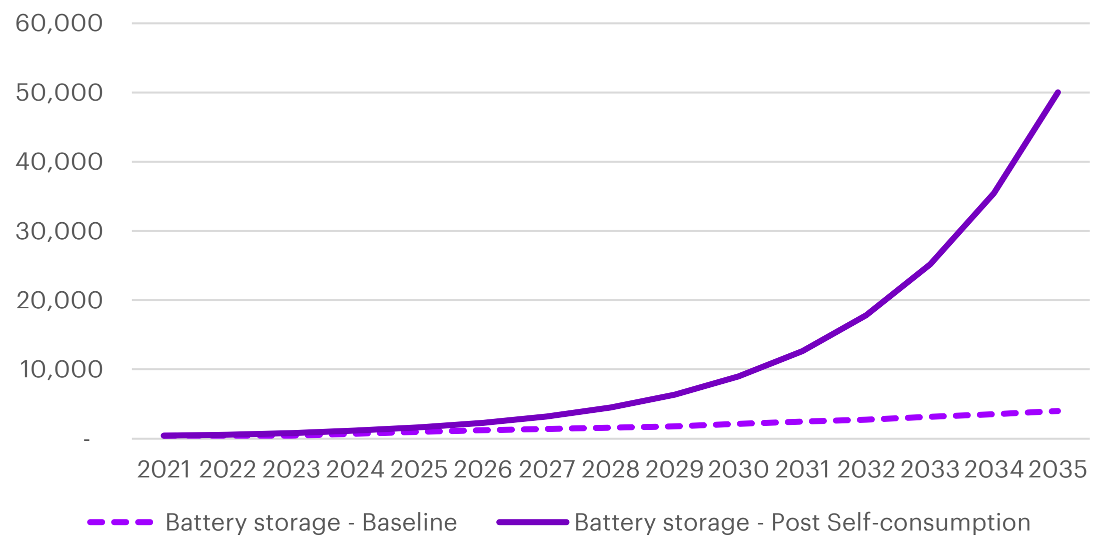
Purpose is to enable greater utilization of distributed solar PV. Additional battery storage enables load shifting, so that solar PV generated during the day-time can be stored in a battery and used after sun-down. This greatly increases **resilience and reliability** by providing a risk hedge against unplanned outages (caused by for example increased extreme weather as climate change impacts hit). **Service quality** can be improved using batteries for frequency control. Finally, batteries increase flexibility through demand response.

- Batteries help **load shift** in all seasons, but particularly in summer, autumn and spring. Load shifting can reduce the risk of negative electricity prices and maximise the value of solar PV. They should be deployed in areas of excess solar generation so that load shifts are most substantial, reducing imported energy from the grid.
- Batteries enable **frequency control** in non-wholesale markets, ensuring one of the critical services currently provided by fossil fuel generation.
- Initial **costs for households and communities** are substantial but increase self-sufficiency and lower utilities bills in the long-term.
- The **embodied emissions** of batteries are high. However, in the long-term batteries will be recycled. Batteries formerly used in EVs may be upcycled for pairing with solar PV.
- Batteries improve overall **system efficiency** through enable more decentralised solar PV to be utilised

Opportunity

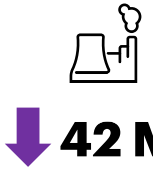
- Increase accessibility of **renewable solar for low-income groups**: Local government can collaborate with agencies to create provide information and accessibility for low-income pensioners by installing affordable solar systems with no upfront costs.
- Assist businesses to enter **power purchase agreements**.
- Incentivise **behind the meter batteries**: Time of Use tariffs further encourage prosumers to use power stored in their battery at peak hours, providing relief to the grid.
- Advance the **Small-scale Renewable Energy Scheme (SRES)**: Help with purchase costs of renewable energy for households and small businesses, pairing batteries with solar PV systems.
- Develop a **clean energy curriculum**: Embed renewable energy curriculum in educational institutions and government agencies to encourage future adoption of renewables.
- Incentivise the uptake of **medium scale solar** for schools and commercial buildings.
- Increase the **minimum feed in tariff (FiT)**.

Projected Battery Storage Capacity (MWh)

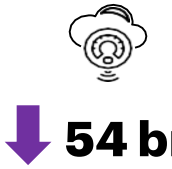


System Value Impacts - Benefits

Benefits

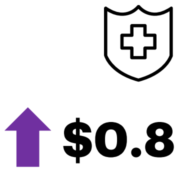


42 Mt
Cumulative electricity base case CO_2 reduction through 2035



54 bn L
Cumulative decrease in water consumption compared to base case through 2035

19.5 K
DER battery installation incremental job impact in 2035



$0.8 B
Human health benefits through 2035

Sources: Department of Industry, Science, Energy and Resources, Clean Energy Council, Department of Environment, Land, Water and Planning, Clean Energy Council (DER Report),

2. Accelerate Electric Vehicle Adoption

100% electric vehicles by 2035 for healthier cities and more flexible demand

Overview

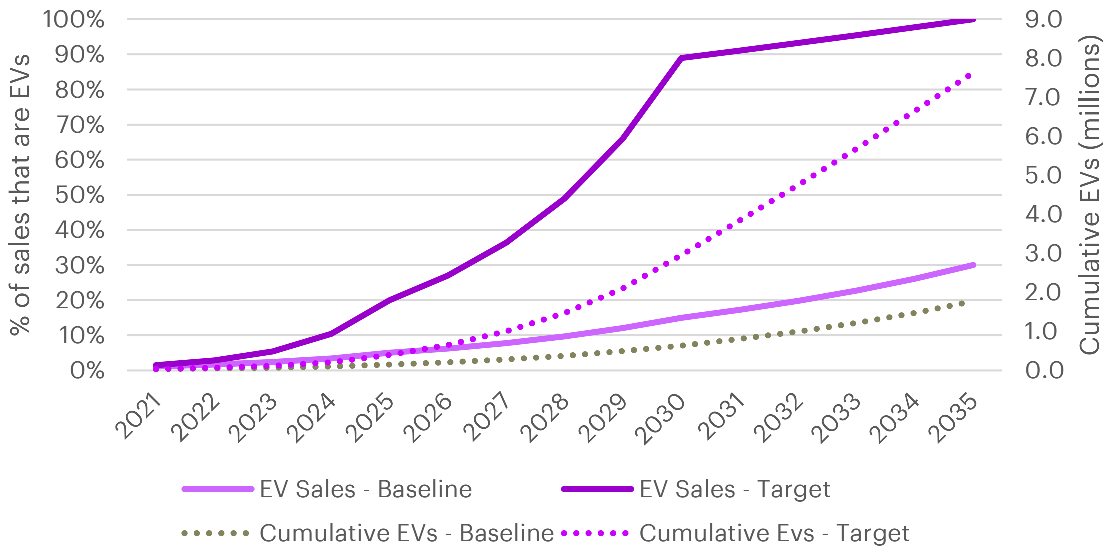
Accelerated electric vehicle uptake will greatly support grid stability and flexibility. Initially, the emissions impacts of EV transformation will be small, but once uptake is high there will be little mining and manufacturing required. Reduced air and sound pollution are other major benefits, as well as new jobs in the battery value chain and infrastructure upgrades. Trucks are out of scope for this analysis, but cars, vans and buses are in scope.

- Transport currently accounts for 19% of Australia's emissions, and road fleet rates are among the least efficient in the world. In 2019, average emissions intensity of a new vehicle was 180.5gCO_2/km, falling less than 1% in the last three years. Increasing the uptake of EVs in Australia will reduce national carbon emissions and contribute to building a national renewable energy ecosystem.
- Current EVs include battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV), and hydrogen fuel cell electric vehicles (FCEV).
- The combination of reduced battery cost and improvements in battery and charging technology has resulted in an increased range of EVs, and consequentially a higher uptake with consumers. Accelerated deployment of EVs may be further enhanced by policy means.

Opportunity

- **Fiscal incentives to encourage adoption:** including public procurement schemes (buses, and municipal vehicles), subsidies at vehicle purchase, parking privileges, road toll rebates, and discounts to registration and stamp duty.
- **More comprehensive policies:** the *National Strategy for Electric Vehicles* requires more depth and clarification on both industry standards and targets.
  - Import regulations: to increase the model availability and overall uptake with third party imports of BEVs and PHEVs.
  - Fuel efficiency regulations (e.g., 105g/km fuel efficiency) to meet compliance and efficiency targets.
  - Bans on global internal combustion engine vehicles: Original Equipment Manufacturers are considering removing ICEs from their vehicle portfolio within the next 10-30 years, but this timeframe could be accelerated.
- Provision of public charging infrastructure.
- Scaling-up the circular economy for batteries (i.e., refurbish, repurpose, recycle).

Projected EV Sales (2022-2035)



System Value Impacts - Benefits

Benefits

↓ **69 Mt**	↓ **158 bn L**	↑ **10 K**	↑ **$0.6 B**
Cumulative electricity base case CO_2 reduction through 2035	Cumulative decrease of water consumption compared to base case through 2035	Increase in net employment by 2035	Human health benefits through 2035

Sources: Electric Vehicle Council, International Energy Agency, ARENA

3. Electrify and Transform Residential and Commercial Energy Demand

More electric appliances for homes and businesses to make the most of abundant solar and reduce network congestion

Overview

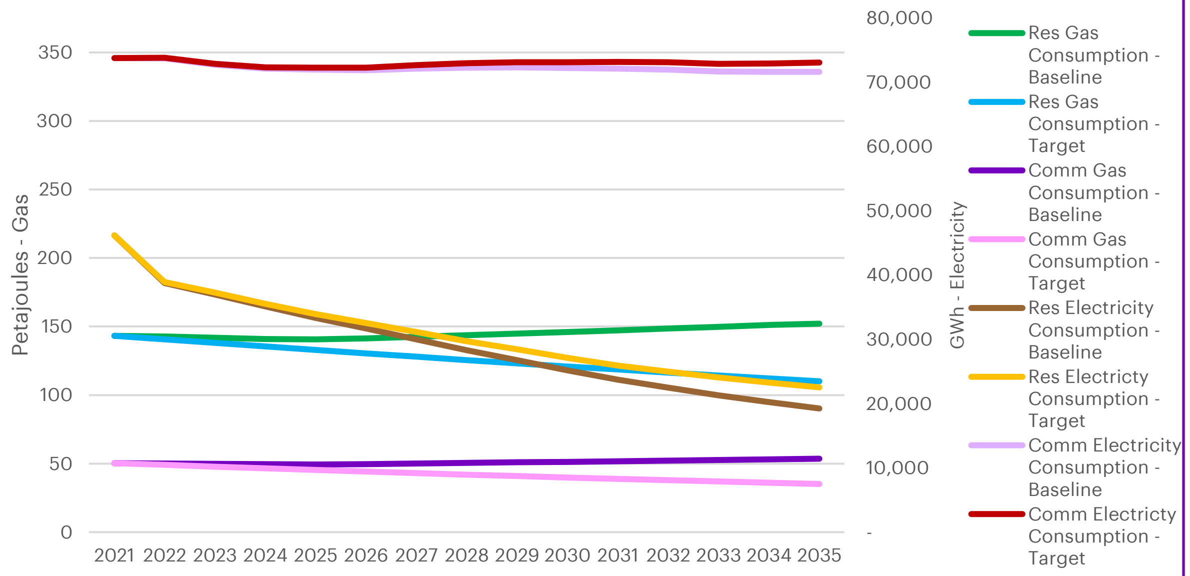
There are carbon emission and grid stability benefits from the electrification of the commercial and residential sectors, but the most pronounced system value impacts come from human health benefits, a medium-term employment boom and increased resilience.

- Commercial and residential sectors still rely on gas as the main energy source for water heating, cooking, space heating/cooling and some appliances.
- Electrification would involve deploying renewable technologies, retrofitting houses, and upgrading appliances.
- Energy demands from commercial and residential sectors can be flexibly managed by also installing storage systems for renewable energy to reduce demand on the grid from increased solar PV uptake. Due to the unpredictable nature of commercial businesses and residential demand, the flexibility demand rates are lower than that of industry.

Opportunity

- **Heat pumps** to replace gas furnaces, and heat pump water heaters to replace gas tank water heaters. Heat pumps have 400% efficiency compared to the best gas boilers which are 95% efficient. Excess heat can be utilised by combining heat pumps with heat storage.
- **Induction/electric cooktops** to replace gas stovetops resulting in increased speed, efficiency and safety.
- **Electrification of space heating** in homes with radiant heating. Split system air conditioners are several times more efficient than their gas counterpart.
- **Electrification of water heating** in homes with gas tankless water heaters
- Commercial sites can utilise **electrochemical, mechanical, electrical, and thermal energy storage systems**.
- Replace lead/acid batteries with more responsive **lithium-ion batteries**.
- Increase the availability of **off-site generation** to provide load flexibility (solar PV).
- **Incentivise system upgrades:** the Small-scale Renewable Energy Scheme (SRES) offers small-scale technology certificates (STCs) for eligible solar water heaters, air source heat pump water heaters, small-scale PV, wind and hydro systems.
- **Create new opportunities for stakeholders:** services and solutions are needed such as providing FCAS, FFR and recovery services, load shifting, and active management of DER.

Gas/ Electricity Consumption & Impact of Electrification



System Value Impacts - Benefits

Benefits

↓ **53 Mt**	↓ **102 bn L**	↑ **112 K**	↑ **$21 B**
Cumulative electricity base case CO_2 reduction through 2035	Cumulative reduction of water consumption compared to base case through 2035	Increase in net employment by 2035	Human health benefits through 2035

Sources: Department of Industry, Science, Energy and Resources, Clean Energy Regulator, Energy Networks Australia, AEMO, ARENA, Beyond Zero Emissions

4. Electrify Industries, Generate Hydrogen & Establish Industrial Clusters

Electrifying industry requires production of hydrogen for high-temperature processes. This can be exported to provide an export industry. Industries can be co-located in clusters to enable circular re-use of resources

Overview

- Move directly to electrification for low-temperature processes, using heat pumps which have higher efficiencies than gas boilers
- For high-temperature processes, hydrogen will be required. This can be created through the electrolysis of water. When the hydrogen is burnt, the water is reclaimed
- Establishing industrial clusters that are powered by renewable energy will achieve operational efficiency providing economic benefits of billions of dollars and hundreds of thousands of jobs for the zero-emissions economy (renewable hydrogen, ammonia, green steel, aluminium and other metals).
- A network of 13 industrial clusters has been identified by National Energy Resources Australia (NERA) to drive market activation, establishing a global identity and recognised brand in the emerging hydrogen industry.[1]
- The Renewable Energy Zones described in the ISP, or decommissioned coal plant sites provide ideal locations for industrial clusters – with transmission line connectivity already and with highly skilled work-forces already required

Opportunity

Government partnerships and investment

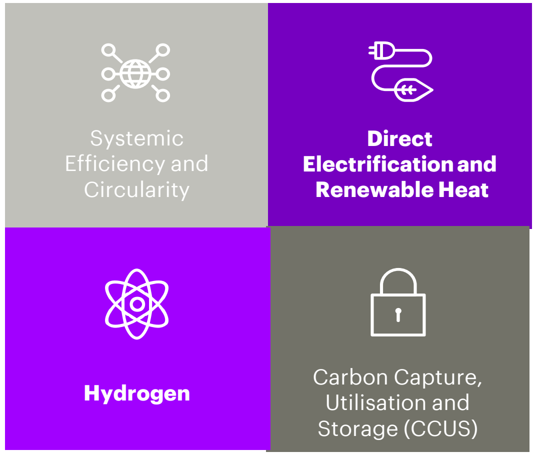
- **Partnering with organisations** such as National Energy Resources Australia (NERA), to establish new clusters[1]
- Developing **Hydrogen Technology Cluster Australia (H2TCA)** to establish a global identity that aids the development of hydrogen supply chain, identification of development gaps, deployment, reducing overlaps, and commercialisation of new hydrogen focused technologies[1]
- Accelerating and actioning **renewable energy strategies at a state level**. E.g. Queensland Government's Hydrogen Industry Strategy

Investment into new technologies

- **Resource recovery**: circular economy for waste
- **Hydrogen production** powered by on-site renewables (producing "green hydrogen")
- **Renewable ammonia** produced by renewable hydrogen: for example, a large-scale chemical complex at Gladstone would produce around 550,000 tonnes of ammonia.[3]
- **Wind turbine manufacturing**: for example, 300MWh of blade capacity could be produced in a proposed Queensland REIP (renewable energy industrial precinct).[3]
- **High purity alumina** for clean-tech appliances such as batteries and LEDs.[3]

Industrial Cluster Focus Areas

Of the four net-zero solutions for industrial clusters, we have investigated **direct electrification** and **green hydrogen** interventions for Australia.



- Light industry will electrify rapidly.
- Heavy industry will take longer to electrify.
- Electrified processes are, on average, more efficient.
- Industrial flexibility will increase exponentially.
- Green hydrogen as feedstock replaces fossil fuels in industrial processes.
- Industrial clusters use 100% renewable energy.

System Value Impacts - Benefits

Benefits

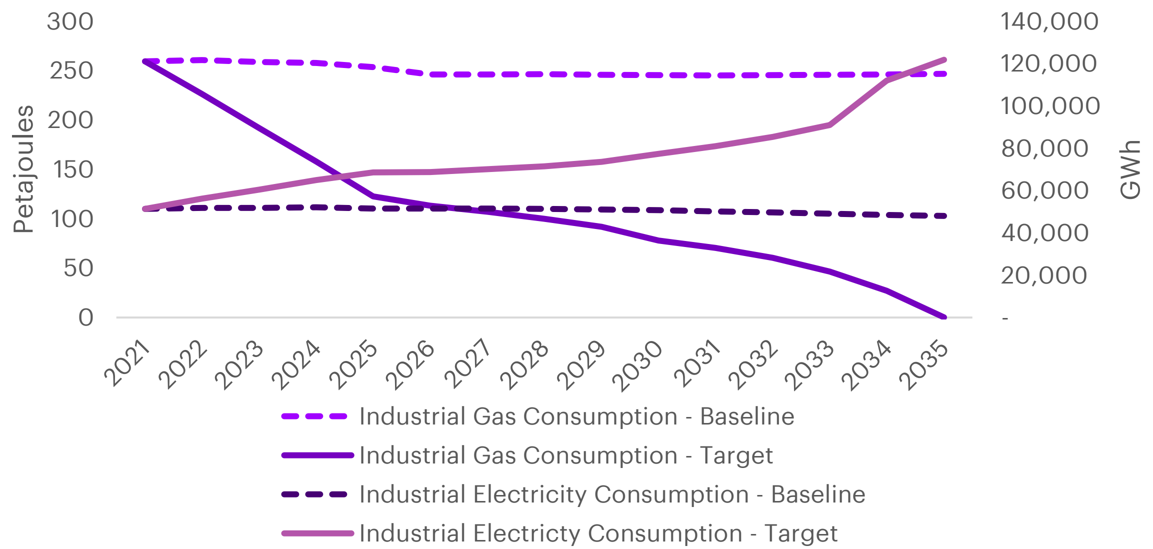
↓ **285 Mt**	↑ **92 bn L**	↑ **198 K**	↓ **$5.12 B**
Cumulative electricity base case CO_2 reduction through 2035	Cumulative additional water consumption compared to base case through 2035	Utility-scale solar incremental job impact through 2035	Human health cost savings through 2035

Sources: 1. National Energy Resources Australia, 2. Beyond Zero Emissions, 3. ACIL Allen Regional Economic Impact Analysis

4. Electrify Industries, Generate Hydrogen & Establish Industrial Clusters

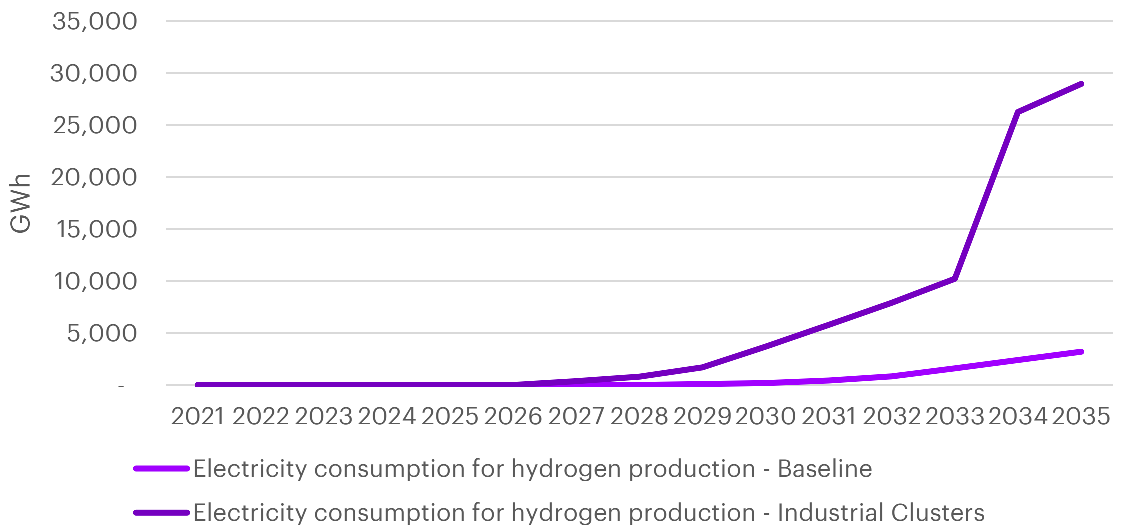
This model assumes an increase in electrification and hydrogen production

Direct Electrification and Renewable Heat



- **Food and beverages sector:** gas-fired heaters, steam boilers and electrical equipment are used to process food. Opportunities include higher efficiency heating (electric heat pumps) and infrared heating, which can be three times more efficient than gas ovens.[5]
- **Pharmaceuticals, chemicals and plastics sector:** steam and other low-temperature processes in smaller chemical manufacturing plants can use four main electrical alternatives instead of fuel-based steam systems: heat pumps, mechanical vapour recompression, electric resistance boilers and microwaves.[5]
- **Wood, pulp and paper:** paper drying can be electrified with the use of heat pumps and the retrofitting of existing conventional steam dryers to use electric infrared.
- **Heavy industry:** replacement of centralised gas boiler systems with heat pumps, electrified process heat, electromagnetic heating, electrical resistance (for the glass industry), electrified iron ore haulage, electric are heating and green hydrogen and steel.[2 3]

Hydrogen Production for Australian use

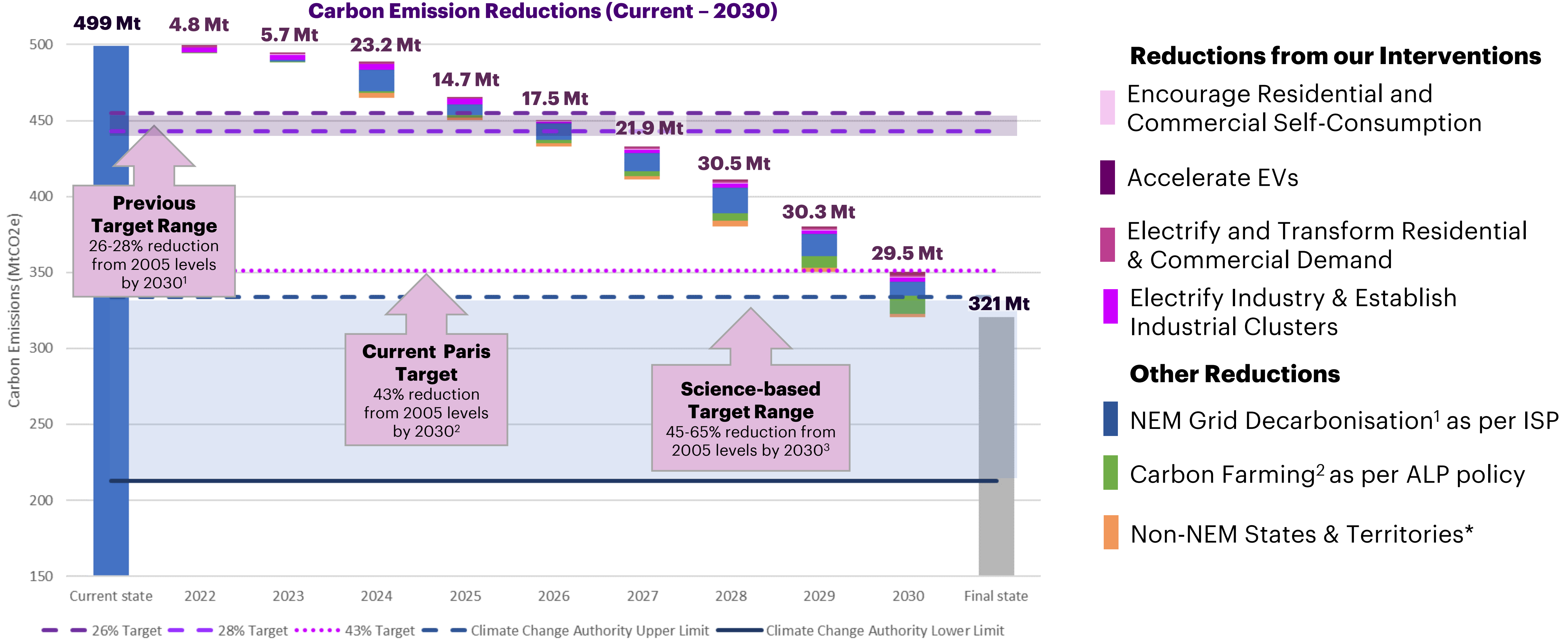


- The amount of **hydrogen generated for domestic use** is greatly increased.
- Because hydrogen is produced in industrial clusters, it uses **100% renewable energy**. It can therefore be considered "green hydrogen".
- Industrial clusters begin to produce green hydrogen in **2027**.
- The green hydrogen is a **non-emissive energy source for industrial processes**, replacing processes that depend on gas and are hard to electrify.
- The System Value Analysis does not model **green hydrogen production for export**.

Sources: National Energy Resources Australia, Beyond Zero Emissions, ACIL Allen Regional Economic Impact Analysis

To meet 2030 emissions targets, demand-side interventions need to be complemented by the acceleration of grid decarbonisation

Achieving Australia's new Paris target of 43% reduction of 2005 levels by 2030 can be assisted through these demand-side interventions, leading to us beating the 43% target

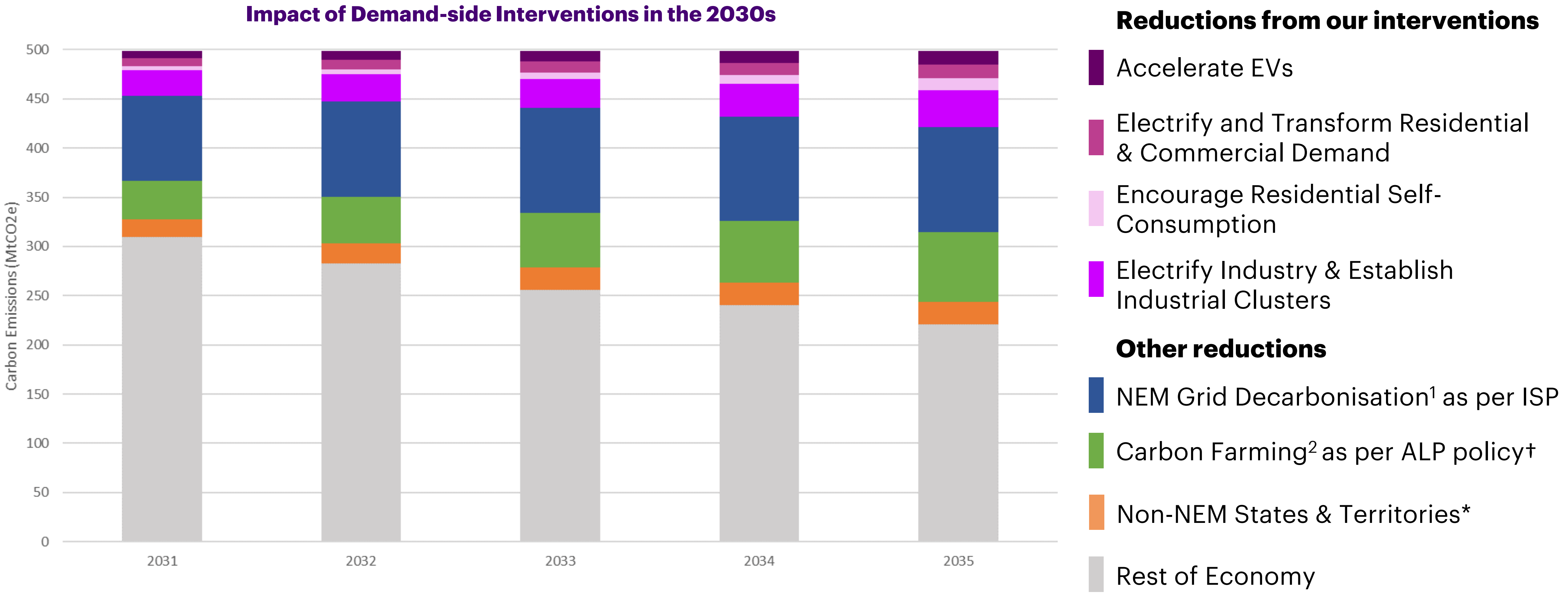


Source: 1 Australia's emissions projections 2022 (November 2022) *Department of Industry, Science, Energy and Resources* 2. Powering Australia Plan (2021), Australian Labor Party 3. Final report on Australia's future emissions reduction target (2 July 2015), Australian Government Climate Change Authority.

* Assumes that other states and territories decarbonise their grids at a similar rate to the NEM.

Demand-side interventions become much more impactful in the decade following 2030 (i.e., for a 2035 or 2050 emissions target)

More importantly, the demand-side interventions start to substantively accrue in the 2030's, reducing Australia's emissions by an additional ~72 Mt CO_2e per year by 2035



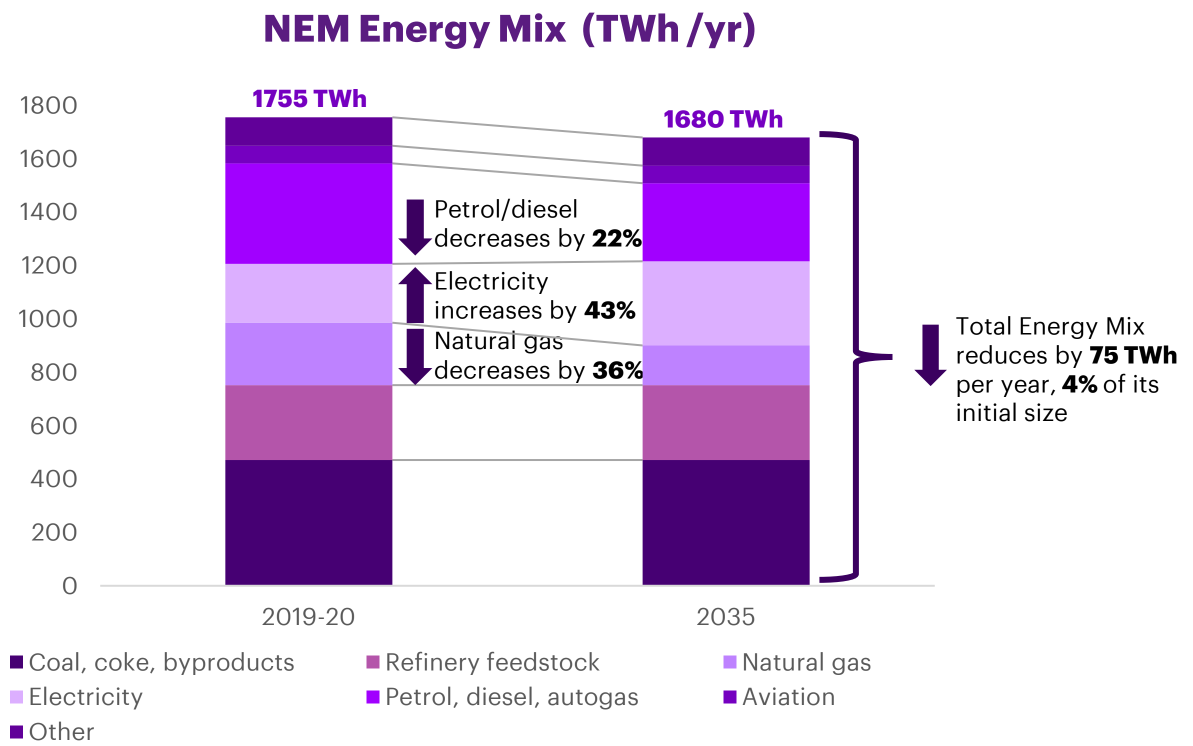
Source: 1 Australia's emissions projections 2022 (November 2022) *Department of Industry, Science, Energy and Resources* 2 ALP'S Powering Australia Plan.

* Assumes that other states and territories decarbonise their grids at a similar rate to the NEM.

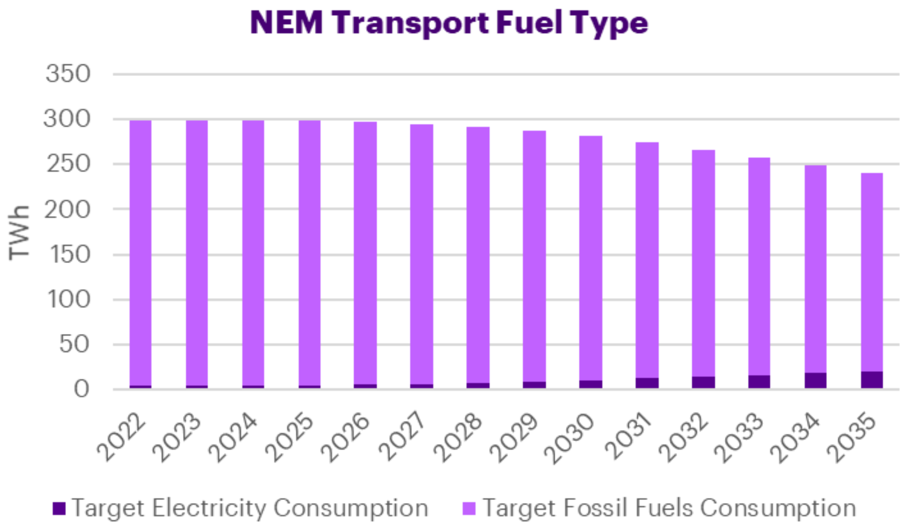
† Assumes that carbon farming initiative will continue at a consistent rate after 2030.

These interventions change the energy mix and reduce the total use of energy through increased energy conversion efficiencies

Shifting to electrification across the demand side reduces national primary energy input into the energy system since electrification is more efficient – we model a 4% reduction in energy usage overall



The increased electricity efficiency over other fuels will reduce the NEM Energy Mix by 4%, compounding all other benefits of decarbonisation and reducing costs.



Electric vehicles are significantly more efficient than petrol and diesel. Switching to electric vehicles, therefore, reduces Australia's overall transport energy usage by 20%.

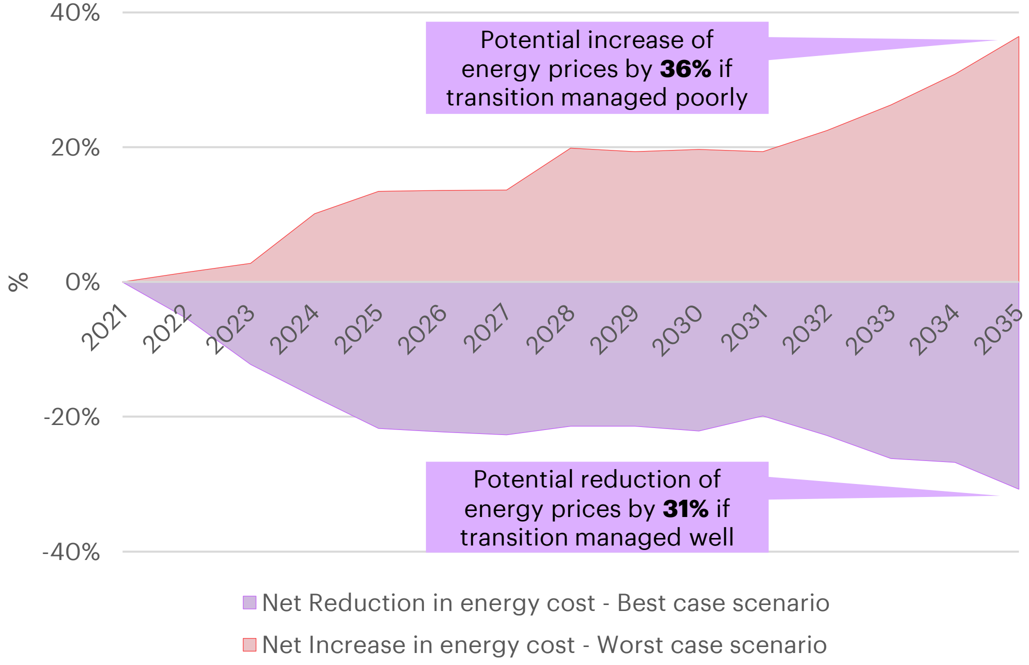
Source: Australian Energy Statistics, Table F1, Department of Industry

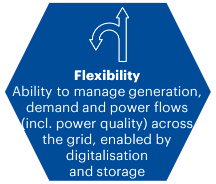
*This chart assumes that the energy mix in 2022 is the same as that of 2019-20 (the most recent available data).

The interventions reduce energy prices for ALL Australians, whether they have bought new energy products or not

Electricity prices go down due to more efficient utilisation of network and generation assets (fixed costs spread over a larger base)

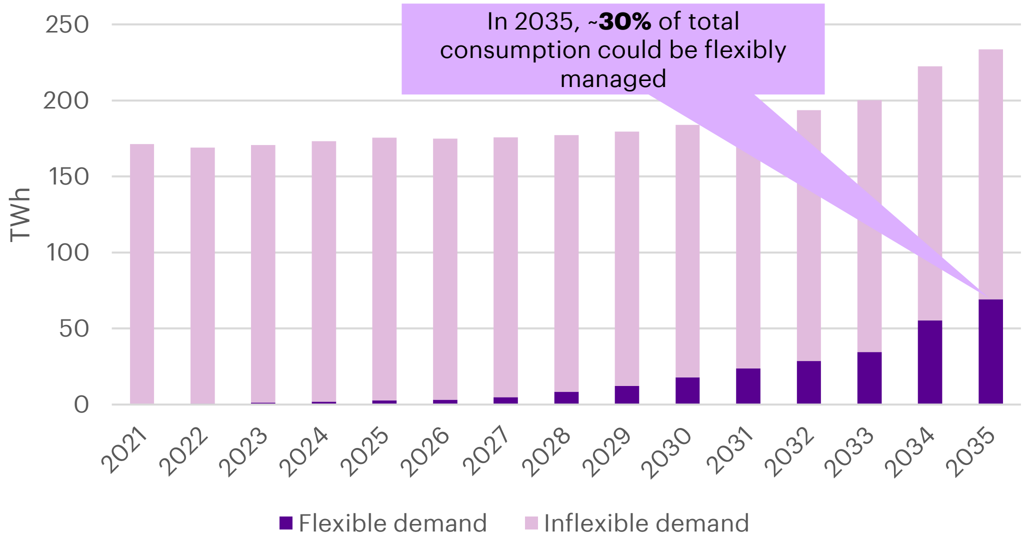
Electricity Price Changes





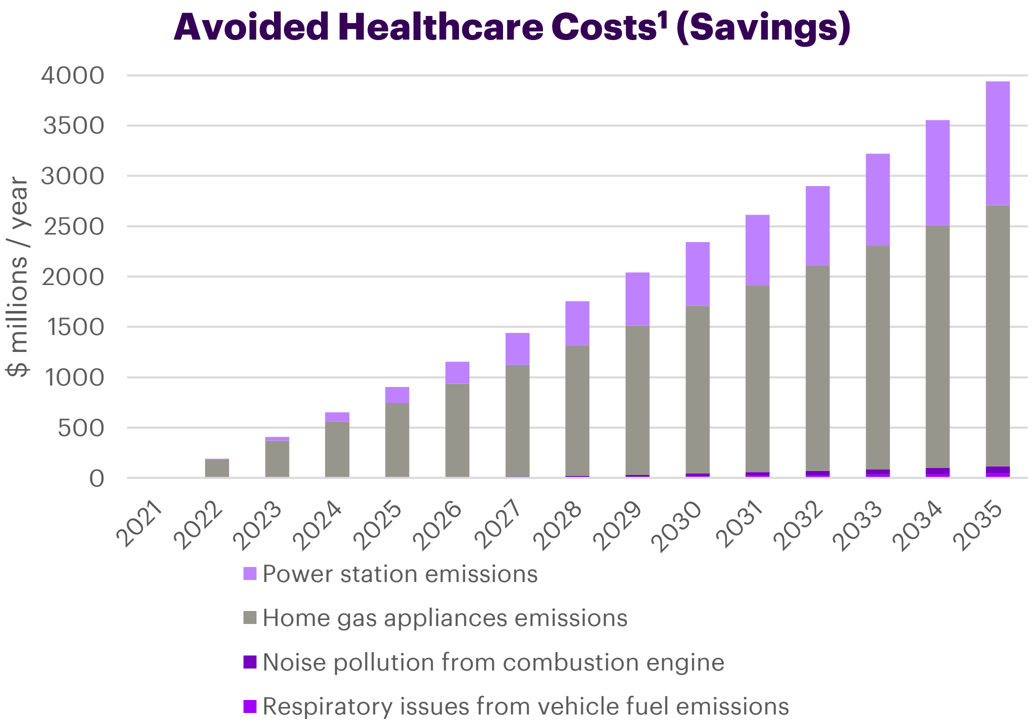
Increased dispatchable demand that can be controlled by distributors and generators to balance supply and demand and protect grid assets, enabling the last 20% of decarbonisation to be done at least cost

Electricity demand



Hidden health costs of the current status quo are relieved, providing bottom line budget savings of nearly $4b per year in 2035

Reduction in harmful pollutants (PM10, PM2.5, NO_x, SO_2) and in noise pollution. This improves respiratory health (incl. asthma) and mental / physical health through reduced stress.

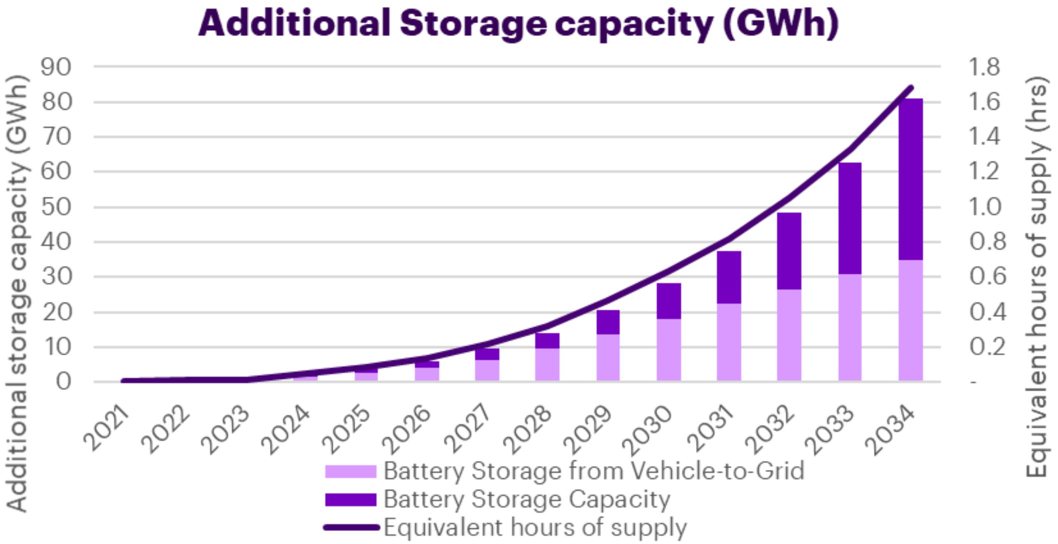


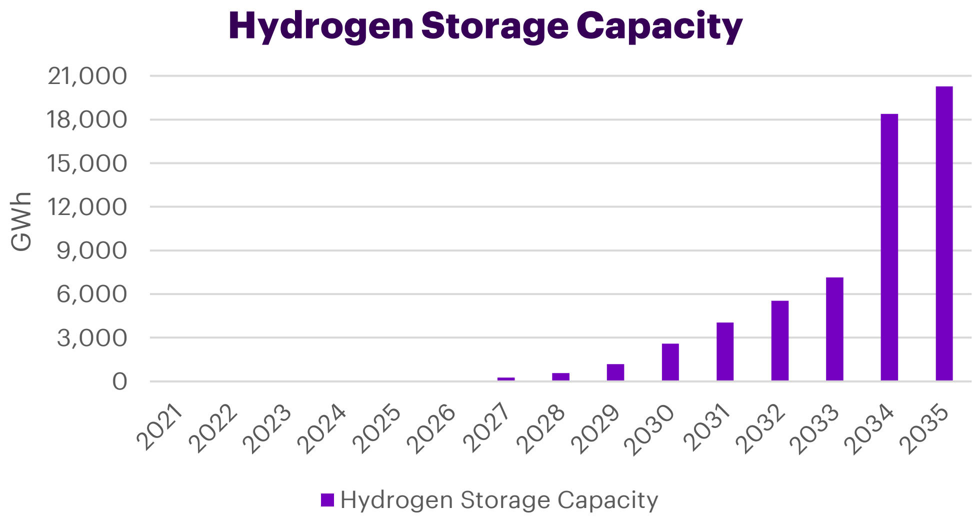
[1]Avoided Healthcare Costs reflect saved "bottom-line' medical costs associated with these interventions (e.g., reduction in hospital costs associated with pollution-related respiratory illness).

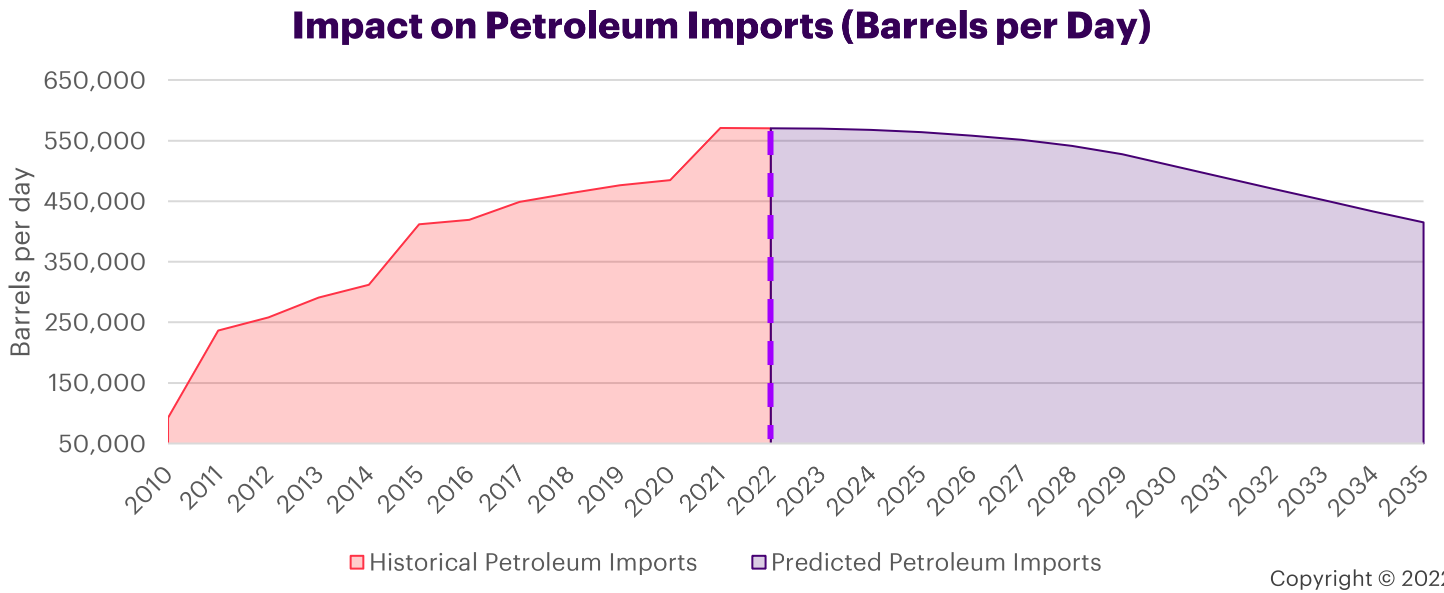
If additional measures such as the economic output of longer life expectancy and improved quality of life (the 'value of a statistical life' of $222K per life-year) are included, this benefit increases **by an order of magnitude.**

Interventions can also improve individual and national energy resilience to natural disasters and external security threats

Additional storage capacity from vehicle-to-grid, added battery storage capacity and from hydrogen. Less demand on combustion engine car will reduce the demand for petroleum import







Interrelationship between the Interventions

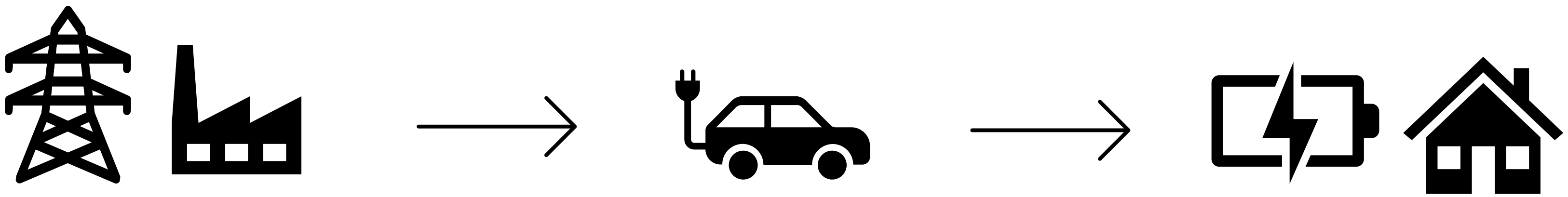
The interventions each have the potential to make a significant impact, but when implemented simultaneously the increased maturity of one sector can support growth in others. Solutions 1, 3 and 4 can unlock significant additional value when strategically aligned to address limiting factors.

Overview

- The System Value Analysis investigated the impacts of three interdependent interventions: (1) Accelerated adoption of electric vehicles, (4) Electrification of industrial demand and (3) Encourage self-consumption.
- Implementing all three solutions presents with the potential opportunity to multiply the benefits. This can subsequently accelerate the path to achieving net zero.
- The embodied emissions associated with multiple activities will be reduced on the implementation of our interventions, which will be further amplified downstream.

Opportunity

1. Batteries are associated with high embodied emissions due to the carbon intensive mining and mineral processing steps involved. **Electrifying and transforming industrial demand** (solution 4) means that this battery emissions can be further reduced. **Accelerated adoption of electric vehicles** (solution 1) coupled with less carbon intensive batteries can further transform the overall emissions associated in the transportation sector. The EV batteries at the end of their lifecycle can be adopted for home batteries for **self consumption** (solution 3) which means the initial embodied emissions will be zero (or negative). Also, more EVs mean more batteries will be available for residential and commercial utilisation, thus ensuring a circular economy.



Solution 4: Electrification of industries bring down the embodied carbon emissions in batteries

Solution 1: Electric vehicles can utilise less carbon intensive batteries and reduce the overall emissions in transportation

Solution 3: Electric vehicle batteries at the end of their lifecycle can be upcycled as home batteries. This battery will have zero embodied emissions

Vehicle-To-Grid Impact

In the near future, we predict that vehicle-to-grid technology will enable electric vehicles to function as home batteries. EV batteries will not be as efficient for powering buildings as purpose-built residential batteries, but will still increase the total storage capacity. This means the outcomes for the Self-Consumption intervention are greater. In total, combining the two scenarios will yield an **additional 43 Mt CO_2e emissions reduction** by 2035

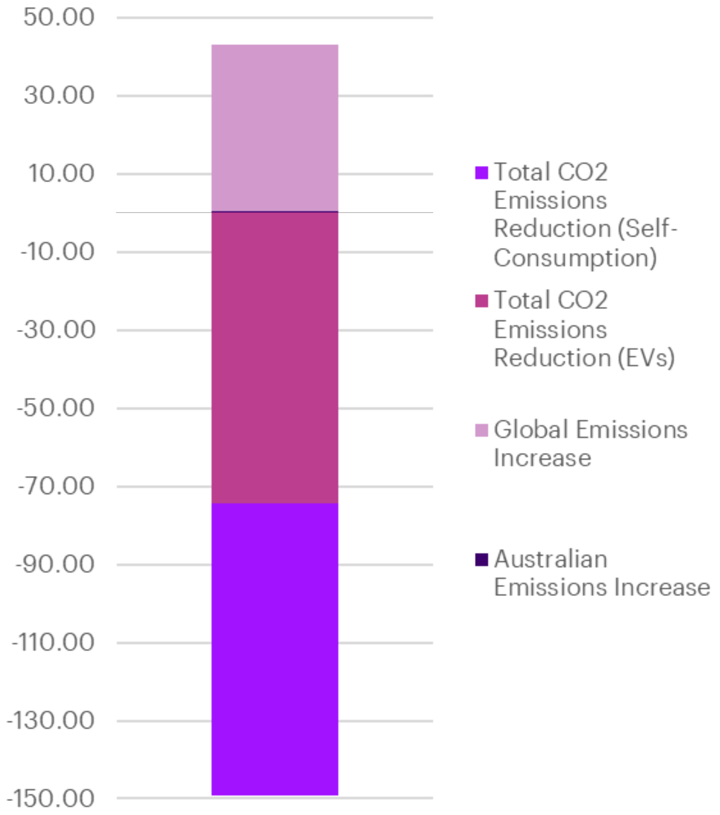
Emissions Increase

- Globally, the embodied emissions of electric vehicles and batteries lead to a temporary increase. (Intervention 1 + Intervention 3)
- Australian carbon emissions increase slightly due to the remaining dependency on the grid. This is significantly lower than in Accelerate EVs alone because from 2025 most EVs are charged by rooftop solar.

Emissions Reduction

- Emissions reduce due to the increased efficiency of rooftop solar by using EVs as home batteries.
- Emissions reduce due to the decrease in internal combustion engines. (Unchanged from Intervention 1)

Combined Emissions Impact



Jobs and Economic Impact

Despite its importance in regional Australia, the fossil fuels sector represents only 1% of Australian jobs. The interventions in this analysis help to mitigate job losses and will directly or indirectly create other short- and long-term opportunities

Jobs and Economic Impact
Influx of jobs due to energy transition and renewables

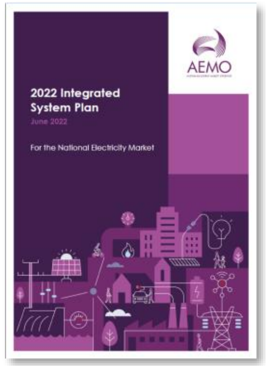
Intervention	Job and Income Losses	Job Opportunities
1. Electric Vehicles	➢ Jobs associated with the **automotive industry** such as **motor vehicle** and **parts manufacturing** will decline[1]	➢ Switching to electrified transport infrastructure would result in a net increase of **13,400 jobs by 2030**[6]
	➢ Jobs such as **fuel retailing** and **maintenance** of internal combustion engine vehicles will no longer be needed[2]	➢ Electric bus manufacturing alone would see the creation of **19,000 manufacturing jobs**[6]
		➢ $500 million investment from the Federal Government in **battery manufacturing** would create **6,800 jobs**[6]
2. Electrify and Transform Residential & Commercial Energy Demand	➢ **Lost income** for property owners due to lower rental payments, and lower rates of building renovation and stock turnover.[3]	➢ Building 150,000 energy efficient social houses could create over **900,000 new jobs** over the **next 5 years**[7]
	➢ Impact on job losses is **marginal**	➢ Upgrading buildings will stimulate jobs **boost in construction, trades and retail**[8]
3. Encourage Self-consumption	➢ Fewer jobs will be needed in the **conventional electricity industry.**[4]	➢ **Small-scale rooftop solar** is the **biggest contributor to jobs** in the renewable energy sector[9]
		➢ There will be a **high demand** for electricians, electrical trade assistants, management, professional, administrative and health and safety services[9]
4. Establish Industrial Clusters	➢ Transitioning out of coal will require an **end** to new development of **thermal coal mines**. Jobs in mines will decline.[5]	➢ There will be a **boost in manufacturing jobs** across a number of different sectors[10]
	➢ Jobs in existing industrial areas will need to be **relocated.**	➢ Renewable energy in Australia has reached a level of cost and maturity to power energy intensive processes and industries, **securing jobs** in the long-term[10]

1. EVC, NRMA, pwc, St Baker Energy Innovation Fund (2018). *Recharging the Economy*
2. Parliament of Victoria, Inquiry into Electric Vehicles (2018)
3. IEA (2020). *Report Extract: Buildings*
4. Yu, M. & Halog, A. (2015). Solar Photovoltaic Development in Australia. *Sustainability, 7*, 1-35.
5. The Australia Institute (2020) *Getting off Coal.*
6. EVC, State of Electric Vehicles (2020)
7. BZE, Million Jobs Plan (2020)
8. ClimateWorks Australia, Recover and Reduce (2020)
9. Clean Energy Council, Clean Energy at Work (2020)
10. BZE, Electrifying Industry (2018)

APPENDIX

AEMO ISP’s “Step-Change scenario” is a realistic, well modelled future low-carbon energy supply system

The step-change scenario describes a rapid decarbonisation of the NEM’s electricity supply. This scenario is considered the **most-likely** scenario amongst the industry and provides a low-carbon energy supply over the next 20 years. This is a pre-requisite for the System Value Framework



The AEMO Integrated System Plan (ISP) is a detailed publication released every two years. It is a **‘whole of system’ plan**, offering a roadmap for development of Australia’s eastern electricity system. It makes recommendations for centralised planning based on the technological, economic and policy environment and offers a view of how we might respond to the challenges of the next thirty years. The 2022 ISP was released in June 2022, modelling four scenarios with different levels of decarbonisation, electricity demand and decentralisation.

The **‘Step Change’ development pathway** focusses on energy efficiency, DER, digital energy and step increases in global policy ambition. It moves quickly to meet Australia’s net zero by 2050 target with a fast-paced transition from fossil fuels to renewable energy. **It is considered the most likely scenario** by energy industry stakeholders.

This includes the following specific supply side interventions:

- Establishment of Renewable Energy Zones
- Build-out of transmission network connecting to those Renewable Energy Zones
- Increase in renewable generation from **45%** of capacity in 2020 to **86%** in 2030
- Total generation volume increases by **50%** between 2021 and 2035

The Step Change Scenario is about a rapid transition of renewables from fossil fuels in the NEM. It’s a consumer-led transition of the electricity sector.
The industry and government sees this scenario as the most likely option to enable a full energy transition.

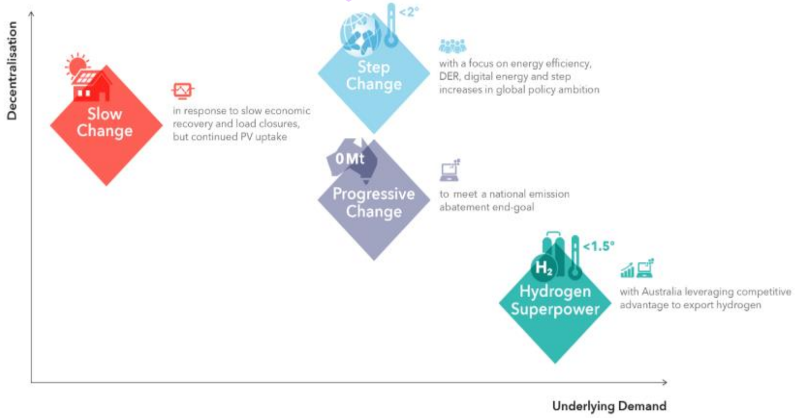


Figure 2:Graph of four different scenarios depicting plausible futures with different rates of decarbonisation. [2022 Integrated System Plan](), AEMO (June 2022).

The ISP *models* various **demand-side factors** as inputs in its scenarios but does not consider the full benefits of them, it just considers them in terms of balancing energy supply and demand. **It is also very conservative in the demand-side modelling, as it does not consider actively intervening.**

Batteries & Electric Vehicles in the NEM

The growth in renewable generation is creating new commercial opportunities in energy storage. Accenture Research predicts that economic gains from Australia's battery industry could almost double between now and 2030, resulting in **$7.4 billion in value added and 34,700 jobs**.[1] Battery power in the NEM includes grid-scale batteries, electric vehicles (EVs) and other small-scale batteries, and pumped hydro energy storage (PHES). By capacity, **25% of new projects in the NEM are battery storage or PHES**[2]

GRID-SCALE BATTERIES

- 5 large-scale batteries have been commissioned since the first in 2017[3]
- According to AEMO, utility-scale energy storage can help to meet the challenges of Australia's **rapidly declining minimum operational demand**
- Lithium-ion battery pack price has decreased 88% since 2010, and is forecast to fall 58% from 2020 to 2030[1]
- In Victoria, a 350MW battery will be developed to close the forecast reliability gap after the closure of a coal-fired power station

PUMPED HYDRO ENERGY STORAGE (PHES)

- Allows hydroelectric plants to **reuse their limited water reserves**
- Currently operates in NSW and Queensland, the largest of which has a capacity of 1500 MW[3]
- Can be more competitive than batteries when **longer duration storage** is needed[4]
- Pumped hydro is the basis of NSW's Snowy 2.0 project (2000 MW) and Tasmania's Battery of the Nation project (2500 MW), as well as a number of smaller projects in NSW and SA[3]

SMALL-SCALE BATTERIES & EVS

- Low battery costs drive the uptake of **EVs and home storage systems**, complementing rooftop solar[5]
- In 2020, small-scale systems (up to 100 kW) were responsible for 23.5% of Australia's clean energy generation and produced 6.5% of the country's total electricity
- Battery storage installations are forecast to reach 5.6GW by 2036-7, up from close to zero in 2022
- In Australia, EVs account for 0.78% of new vehicles sold, contrasted with 2.5-5% across developed countries[6]
- There were 23,000 EV registrations in 2020-21 (out of 20.1 million vehicles), an increase of 62.3% from previous years[7]
- The Australian Government has announced a **$250m Future Fuels Fund** and estimates that 84% of the population will have convenient access to fast charging stations by 2030[8]
- NSW has committed $480m to an EV strategy; Victoria has committed $100m for zero-emissions vehicles
- **Community or medium-scale batteries** of 100kW-5MW are attracting attention both from the public and distribution network service providers.[9] In 2020 they increased by 11MW to 521MW

Sources: 1. Accenture & FBICRC, *Future Charge: Building Australia's Battery Industry* (June 2022)) 2 AEMO, *Electricity Statement of Opportunities* (2022) 3. AER, *State of the Energy Market Report (2022)* 4. Graham et. al.,*GenCost 2020-21 Final Report*, CSIRO (June 2022) p. 68 p.41 5. Energy Security Board, *Post 2025 Market Design* (2022) p. 12 6. EV Council, *State of Electric Vehicles (2022)* 7. Australian Bureau of Statistics, Motor Vehicle Census (January 2022) 8. 'Future Fuels and Vehicles Strategy', *Department of Industry, Science, Energy & Resources* (November 2022). 9. Australian National University, *Community Batteries: a Cost-Benefit Analysis* (2020)
Further Research: A) Electric Vehicle Council, *Recharging the Economy* (2015). B) AEMO, Renewable Integration Study Stage 1 : Appendix A (April 2020). C) AEMO, *ISP Inputs and Assumptions Report* (2019)

Smart EV Charging and Infrastructure

High but flexible energy demand from EVs, can provide a solution to future proof the energy system, but only when effectively managed form the outset. Integrating smart charging into the grid provides efficient management of EV charging times, minimising pressure on the grid during periods of peak demands and reducing the need to invest in infrastructure upgrades. By directly addressing grid constraints, renewable energy availability and EV demand, smart EV charging is future-proof in a constantly changing world

WHAT IS SMART EV CHARGING?

A system that runs on the cloud, where an EV is exchanging data with the charging operator, the electricity grid and electricity supplier through data connections[1]

Smart charging allows users and utilities to intelligently manage, monitor and restrict the use of their devices remotely to optimise energy consumption[1]

Stations are connected to the cloud and can be managed based on various signals: fickle energy production, local energy consumption, number of vehicles being charged, or electrical devices being used on a nearby premise[1]

BENEFITS OF SMART EV CHARGING

Establishing Smart EV charging will have a range of benefits for drivers businesses, and current EV charging networks[1]

Subject	Benefit
EV Drivers	• Safer and faster charging • Save costs and the environment by optimising the timing of charging event to favour charging when electricity is at its cheapest
Businesses	• Enhances business's ability to monitor and control their building's energy capacity, avoiding high demand charges • Brings long-term capital and operating benefits
EV Charging Networks	• Stabilises the grid while ensuring reliable service and quality power • Easily manage the number of smart EV charging stations

WHAT INFRASTRUCTURE IS REQUIRED?

Developing EV charging infrastructure requires significant investments. Governments can incentivise the installation of charging stations either at residential or public access locations. The development of charging infrastructure can initially stem from ambitious EV targets and then focused on specific funding for implementation projects.[2]

In 2020, Australia had **1,950** standard public charging stations and **350** fast charging stations. Considering the 20,100 EV fleet, the ratio between public charging stations and EVs was **1:9**.[3]

Understanding how to best control, aggregate and charge EV load on the grid is an ongoing issue and would impact decisions in the development of charging infrastructure. For example, deciding where to best place charging points, which technology to deploy and how to combine slow smart chargers with fast smart chargers to meet consumers' immediate needs.[3]

WHY IS IT IMPORTANT FOR DISTRIBUTION AND ENERGY COMPANIES?

Network operators have the capacity to optimise energy flow into EVs. Enabling them to regulate energy intake according to peaks and lows in energy demand, providing reliable services to their customers.[4]

A charging system that is flexible and can withstand future surges in energy demand, future-proofs business for grid operators. Operators can optimise the infrastructure to be efficient, convenient and cost-effective for everyone involved.[4]

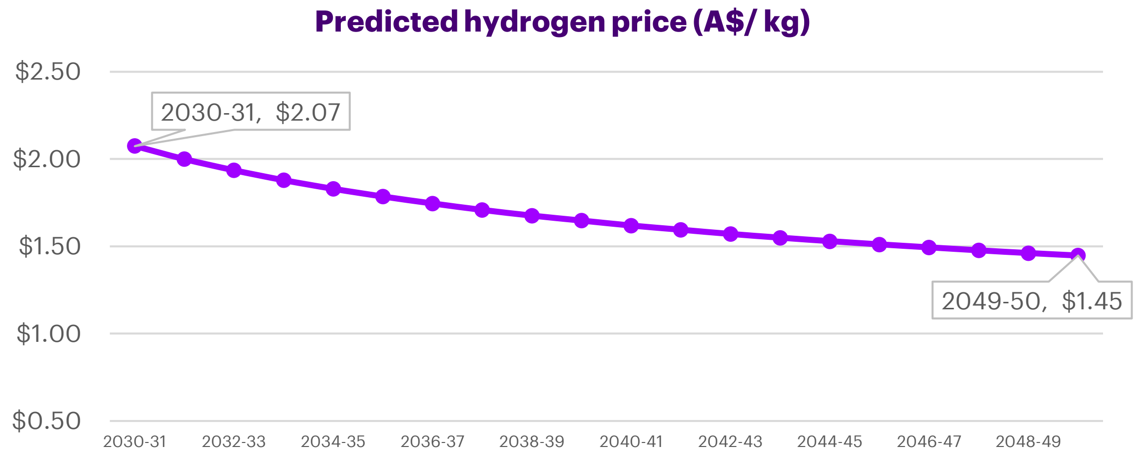
Sources: 1. Virta (2022), 2. IRENA (2019), 3. Energy Networks Australia et al. (2022), 4. Wallbox (2022)

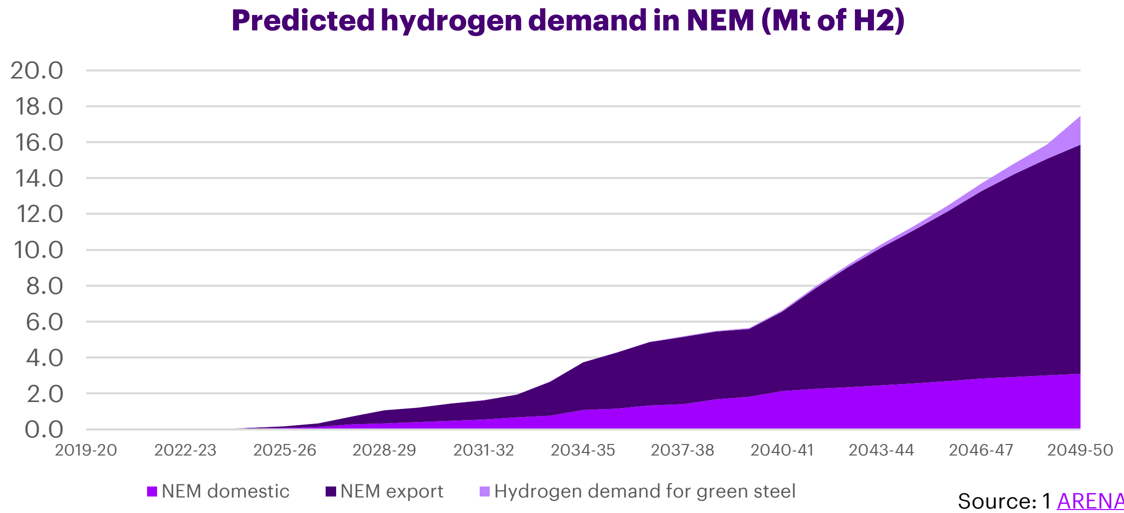
Hydrogen

The Australian Government, along with industry and research collaborators, are accelerating the renewable hydrogen opportunities in Australia. Demand for hydrogen exported from Australia could be as high as over 3 million tonnes each year by 2040, which is valued up to $10 billion each year.[1] The same scenario estimates total global demand of hydrogen at 82 million tonnes per year in 2040[1]

THE AEMO ISP REPORT 2022 CONSIDERS HYDROGEN SUPERPOWER SCENARIO [2]

- The ISP model assumes that hydrogen-fuelled turbines would not be available before 2030 when predicting hydrogen price





COMMONWEALTH GOVERNMENT GOALS & VISION

- Achieve the goal of production of hydrogen at $2 per kg by the Low Emissions Technology Statement
- Commercial export of renewable hydrogen by 2030, as set in the National Hydrogen Strategy

HYDROGEN POLICY INITIATIVES

- National Energy Resources Australia (NERA) invested AUD$1.85 million in 13 regional hydrogen technology clusters across all states and territories
- The FY21-22 budget to include $275.5 million to develop four additional clean hydrogen hubs in regional Australia
- ARENA approved conditional funding in $103 million to three hydrogen projects to Engie Renewables, ATCO Australia and Australian Gas Networks to install 10 MW commercial scale electrolysers

AVAILABLE HYDROGEN RELATED FUNDING [3]

$920m	$325m	$245m
Commonwealth government	State governments	Others

Source: 1 ARENA – Hydrogen energy, 2 AEMO ISP report 2022 inputs and assumptions, 3 Hydrogen policy and project status in Australia

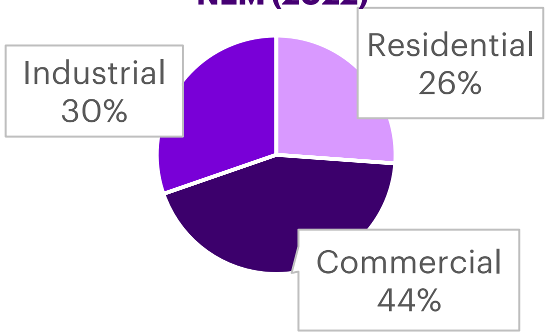
Industrial Clusters in the NEM (and WEM)

Industrial processes currently consume roughly 30% of the NEM's electricity. "Hard-to-abate" sectors depend upon reliable power from the grid. Australia has arrived late at industrial clusters, but it is an increasingly popular concept. Some plans include building clusters around energy sources (Renewable Energy Industrial Zones - REIZ) and integrating renewables exports

HEAVY INDUSTRY IN AUSTRALIA

- Australia is the **world's largest producer** of iron ore and bauxite, and **the second-largest exporter** of alumina[1]
- Mining and manufacturing accounts for 38% of final energy use, and 41% of electricity consumption[1]. The aluminium supply chain is responsible for 9% of Australia's energy use[1]

Building Consumption Mix NEM (2022)



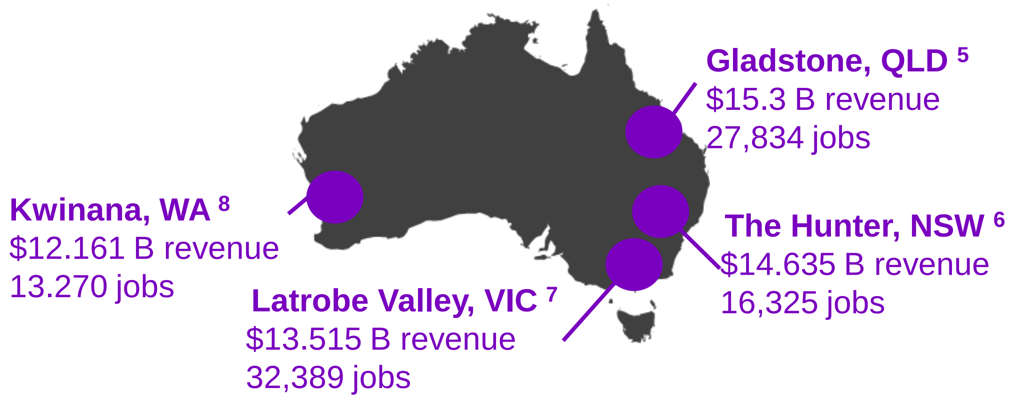
- For non-electrifiable processes: Use of bio-based energy or feedstock is negligible, and hydrogen is made using LNG[3]
- The industrial processes and product use accounted for approximately **30.7 Mt CO_2 emissions in the year 2019-2020** in Australia[4]

GOVERNMENT INITIATIVES

- The **FY22 Federal Budget provides $81.7m over four years** to help realise emissions abatement activities in large industrial facilities

Source: 1. ClimateWorks, Energy Transition Initiative: Phase 1 Technical Report (June 2022), 2. ClimateWorks, Decarbonisation Futures briefing slides (April 2020), 3. Circular economy across Australia – Springer journal paper, 4. Quarterly Update of Australia's National Greenhouse Gas Inventory (December 2020), 5. Remplan, Gladstone Economy, Jobs and Business Insights, 6. Remplan, Singleton Economy, Jobs and Business Insights, 7. Remplan, Latrobe City Economy, Jobs and Business Insights, 8. Remplan, Kwinana Economy, Jobs and Business Insights

OVERVIEW OF A FEW AUSTRALIAN INDUSTRIAL AREAS



Kwinana (not in NEM)

- **Primary industries** petroleum and mineral refineries, power stations, chemical plants, cement works etc.
- **Circularity is present**. 150 product/ by-product and energy exchanges operating on commercial terms currently

The Hunter

- **Primary industries** include mining, energy exports, manufacturing, aluminium and steel
- Proposed REIZ and Hydrogen Cluster
- **Circularity is present.** There are already existing capabilities in steel recycling

Gladstone

- **Primary industries** include LNG, engineering, energy and mining
- Proposed REIZ and Hydrogen Cluster
- **Circularity is present.** Most corporate organisations has large scale efforts to reduce **waste generation and waste energy**

Latrobe Valley

- **Primary industries** include coal power plants, paper manufacturing, oil and gas refineries and steel manufacturing
- **No circularity is present**
- Proposed REIZ and location for Hydrogen Energy Supply Chain project

Net-zero Solutions for Industrial Clusters

There is a menu of abatement opportunities, and a holistic approach to industrial clusters is required to optimise emissions solutions and create an integrated energy system that maximises system value outcomes

Systemic Efficiency and Circularity

- Increase circularity within a cluster through cross-entity waste utilisation
- Integrate processes within a cluster to share energy and material streams
- Provide cost-effective system benefits outside the cluster

Direct Electrification and Renewable Heat

- Electrify low-to-medium temperature and pressure processes
- Generate low-cost, renewable electricity and heat onsite (e.g., rooftop solar, biomass, concentrated solar power)
- Pursue shared infrastructure (e.g., microgrid, storage, flexibility)

Co-located group of industries

Chemicals

Cement

Increased digitalisation and stakeholder collaboration

Manufacturing

Ports

Steel

Hydrogen

- Leverage electricity and heat from nearby zero-carbon sources (wind, solar, nuclear, biomass)
- Produce low-to-zero carbon hydrogen from the most economical source (e.g., blue, green)
- Use produced hydrogen as an alternative fuel for hard-to-electrify industrial processes, building heating and transport

Carbon Capture, Utilisation and Storage (CCUS)

- Capture carbon from energy and hydrogen production
- Use captured carbon for industrial and manufacturing processes
- Store carbon underground where feasible

Light Industrial Energy Use

Light Industry can be energy-intensive, but provides a number of quick wins when compared to hard-to-abate sectors like mining and manufacturing

Food and Beverages Sector[1]
Majority of the manufacturing processes in the food and beverage sector relies on **natural gas.** It is commonly used for cooking, sterilizing, pasteurizing and drying.

Heat pumps are a great solution to electrifying this sector with the potential to replace **95PJ** of fossil fuel combustion, **eliminating almost 5 million tonnes of emissions** and the ability to achieve energy efficiencies of **300%-700%.[2]** If the industry switched to heat pumps, **gas reliance** is **reduced** by **50%-100%.[2]**

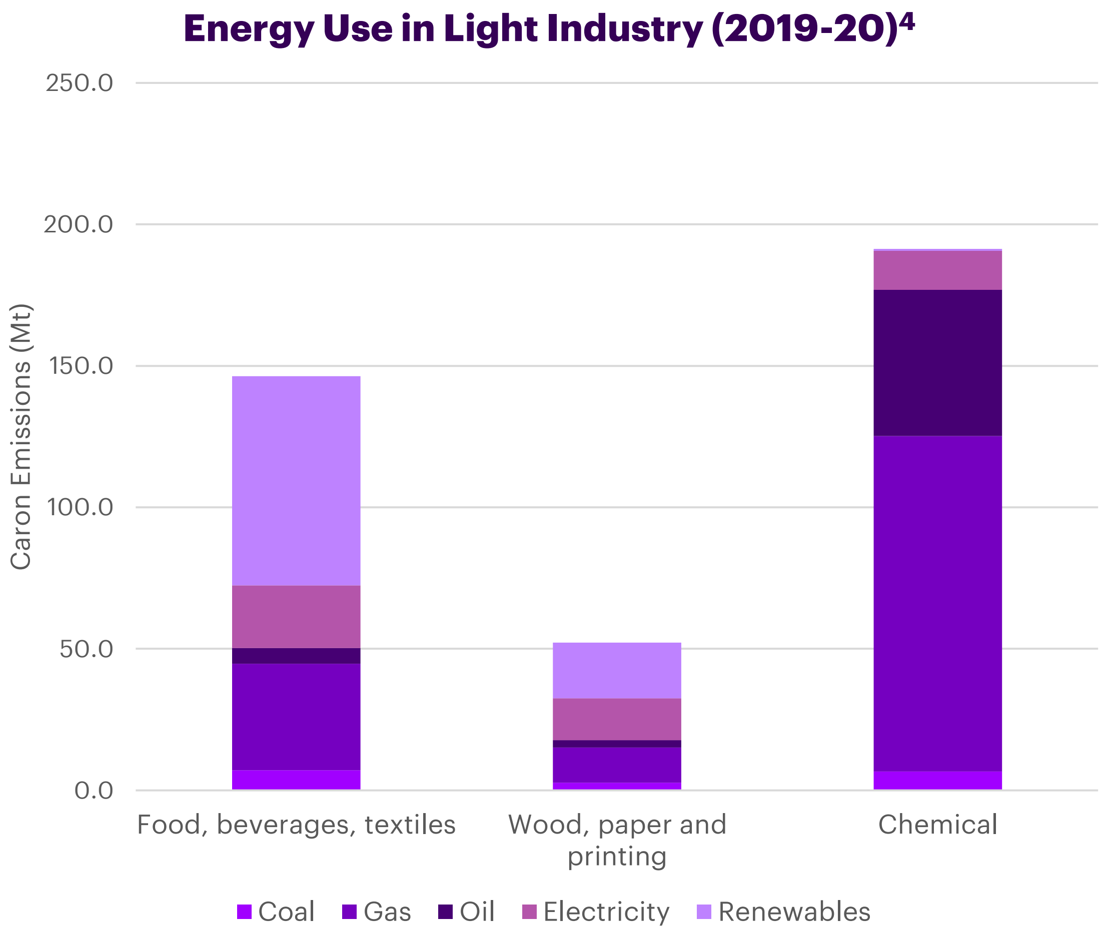
In the **wine sector,** there are opportunities present to adopt alternative energy sources such as **electric** and **hydrogen fuel** to transform the transport system and freight services.[3]

Pharmaceuticals, Chemicals and Plastics Sector – Overview
The **pharmaceuticals & chemicals sub-sector** accounts for approximately **18%** of energy use within the Australian manufacturing sector[4] and mainly uses **gas and electricity** to fulfill their energy requirements.[1] The **plastics sector** is **energy-intensive** and manufacturing requires more energy than steel. Both plastic manufacturing and recycling processes can be **electrified** to reduce fossil-fuel use.[5] Natural gas is also used as feedstock in manufacturing.

Wood, Pulp and Paper Processing– Overview
Major energy requirements take the form of steam and hot water which is generated mostly by **gas** and to a lesser extent **coal.**

Sites using coal as a heat source are on a larger scale and are able to access cost-effective supplies with a much lower price (around **$5/GJ** as opposed to **$10-15/GJ** for **gas** and **$120/GJ** for **electricity**). Smaller-sized plants have energy costs close to domestic supply prices.

Opportunities for alternative energy sources include **bioenergy**, **solar thermal** for all low-temperature tasks. Switching to biogas, biomass can reduce fossil-fuel based energy by **100%** in the medium term (**5-15 years**).[2]



Source: 1. itp et al. (2019).), 2. Northmore Gordon (2022), DISER (2020) 3. InfrastructureSA (2019), 4. Forest and wood products (AISC, website)), 5. BZE (2018), Further research: A) Climate change research - bioenergy (AWE, website) B) Australian Energy Statistics, Table H, Department of Industry, Science, Energy and Resources (September 2020)

Onshore Wind in the NEM

Onshore wind generates almost a quarter of Australia's renewable energy in the NEM[1]. To maximise efficiency and reliability, wind farms are often paired with solar farms and/or energy storage technologies[2]. Renewables such as wind energy can provide frequency control ancillary services to help balance the grid and add power. Victoria currently has 25 registered onshore wind farms, generating 3,105 MW[3]

The diversity in wind generation across different states in summer and winter peak seasons requires stronger interconnectivity to fill in supply gaps

$1.77b ARENA has invested $1.77 billion in total, funding 602 wind-related projects[2]

16 GW At the end of 2018, 94 wind farms delivered nearly 16 GW of wind generation capacity in Australia[2]

35.9% Wind delivered 35.9% of total clean energy generated in 2020 and represented 9.9% of total electricity generation[4]

New wind farms will deliver electricity below $50/MWh by 2030 compared to the current rate of $50-65/MWh[5]

CASE STUDY: AGNEW RENEWABLE ENERGY MICROGRID[4]

- The Agnew Renewable Energy Microgrid in WA will be Australia's first mine to be powered by a wind, solar, battery and gas microgrid including:
  - An 18 MW wind farm
  - A 10,710 panel 4 MW solar farm
  - A 13 MW / 4 MWh Battery Energy Storage System
  - Underpinned by an off-grid 21 MW gas/diesel engine power plant
- This project started in 2019 and is estimated to have an installed capacity of 56 MW – equivalent to powering 11,500 homes or removing 8700 cars off the road whilst abating 46,400 tonnes of CO2 in the first year
- The microgrid is forecast to deliver up to 60% renewable energy to the Agnew mine
- Over 215 new jobs will be created across the 12-month construction phase, and 6 ongoing jobs during operations
- This project acts as a pioneer for renewable energy in the mining industry and an exemplar for an off-grid hybrid power system

Source: 1. AEMO (2022). Market data, 2. ARENA, Wind energy, 3. Aneroid Energy, 4. Clean Energy Council, 5. ARENA (2022). Projects,

Offshore Wind in the NEM

Offshore wind has not yet established itself in Australia. The comparative risk of offshore construction (compared with solar and onshore wind) and lack of a clear regulatory framework have held investors back. In September 2022, federal legislation was introduced for a regulatory framework (the Offshore Energy Infrastructure Bill)

Researchers predict that offshore wind may have the potential to help the NEM transition away from baseload coal.[1] However, it is not expected to significantly contribute to NEM's energy mix before 2030

2 TW

2 TW of offshore wind generation capacity could be installed in Australia within 100km of existing substations[1]

25 GW

International investors have identified opportunities for over 25 GW of offshore wind projects[1]

4 candidate offshore wind zones (OWZs) have been identified by AEMO: two in New South Wales, one in Victoria and one in Tasmania[2]

In Australia in 2020, offshore wind generation capital costs were $5771/kW, compared with $1951/kW for onshore wind[3]

CASE STUDY: STAR OF THE SOUTH[4]

- Star of the South is Australia's first proposed offshore wind project
- It is proposed to be located off the south coast of Gippsland in Victoria's south-east, in a 496-square-kilometre area
- If constructed, it is expected to be operational in 2030
- The project has been approved for exploration, and will submit environmental reports in 2023
- It may provide as much as 2.2GW generation capacity
- Approximately 2000 jobs will be created for its construction, and 200 ongoing jobs
- It will connect to the grid in the Latrobe Valley, taking advantage of existing transmission infrastructure in thermal coal generation heartland
- The wind farm would help compensate for the loss of the Latrobe Valley's Yallourn Power Plant (1.48GW), due to retire in 2028

Source: 1. Blue Economy Cooperative Research Centre, *Offshore Wind Energy Report* (July 2022) 2. AEMO, *2022 Inputs, Assumptions & Scenarios Report*, p. 92 3. Graham et. al.,*GenCost 2020-21 Final Report*, CSIRO (June 2022), p. 68 4. *Star of the South* (2022)

Solar Market in the NEM

Solar PV generated approximately 10 per cent of Australia's electricity in 2020-2022

Renewable energy generation has × 2 in the last 5 years. Today it accounts for over a ¼ of Australia's electricity supply, increasing from 14.6% in 2015 to 27.7% in 2020

The renewable energy industry now employs more than 25,000 Australians

Low Voltage Solar Network (< 10kW)

- 2.96 million Low Voltage Solar PV installations in Australia as of 30 September 2022, with a combined capacity of over 23.5 gigawatts[1]
- Australia leads the world in installed capacity on a per capita basis with 600 W/person, almost eight times the worldwide average of 83 W/person[2]
- Today around 3 million Australian homes have rooftop solar PV.[3] In contrast there were only 14,000 solar PV systems installed on Australian rooftops in 2008[4]

Medium Voltage Solar Network (10-100kW)

- In 2020, medium-scale solar was responsible for 23.5 per cent of Australia's clean energy generation and produced 6.5 per cent of the country's total electricity[3]
- In 2020 the Medium-scale solar sector added 117 MW of new capacity in 2020[3]
- As of 2020 there was 521 MW of capacity in the medium-scale sector with the size of the industry more than doubling over the 2019-2020 period[3]

Large Scale Solar Farms (>50MW)

- There are currently 26 Large Scale Solar Farms operating across Australia with a capacity of over 50MW[4]
- 42 Large Scale Solar Farms with a capacity of over 50MW are in the development process[4]
- In 2018 only 0.8% of Australia's total electricity generation came from large-scale solar farms [4]
- The Darlington Point Solar Farm is Australia's largest operation Solar Farm with a capacity of 336MW[5]

Concentrated Solar Power (CST)

- At present, CST is not competitive with other large-scale renewables, such as solar PV and wind for electricity generation in Australia
- Australia currently has one large-scale solar thermal plant a 9.3 MW facility that has been added to the Liddell coal-fired power plant in NSW. It covers 18,490 square meters[6]
- Barrier to implementing CSP is the relatively high cost of the technology in comparison to more established forms of renewable energy

Government Policies & Initiatives:

- Investments of around **$3.04 billion in solar**, $2.96 billion in energy efficiency, and $540 million in storage, grid and off-grid technologies between 2014/15 – 2019/20[3] by Federal Government, Australian Renewable Energy Agency (ARENA) and the Clean Finance Energy Corporation (CEFC)
- Project EDGE (Energy Demand and Generation Exchange) endorsed by ARENA will demonstrate an off-market DER proof-of-concept in the Hume region of north-east Victoria which can then be replicated across the NEM network
- Australian Solar Thermal Research Institute (ASTRI) is undergoing a $87 million international research collaboration spanning eight years to position Australia in concentrating CST power, and deliver reduced costs and dispatchability improvements
- Government continually supports voluntary emissions reduction through the *Emissions Reduction Fund*, encouraging business and residential uptake of solar

Goals:

- Average wholesale electricity **price under $70 per MWh** to be competitive with NEM's conventional mid-merit gas generation[6]
- *Electricity Network Transformation Roadmap* estimates that DER will contribute up to 45% of Australia's electricity generation capacity by 2050. By 2027 over 40% of energy customers will use DER, increasing to **over 60% by 2050**[7]

Source: 1. Australian PV Institute 2. New Homes and Solar PV, CSIRO3. Solar, Clean Energy Council 4. Solar Farms Australia, CanstarBlue 5. Solar Energy Projects, Brunel 6. Solar Thermal, Clean energy council 7. ARENA (2020). Victorian DER Marketplace Trial, Further research: A) Solar PV and Batteries, DCCEEW B) Solar Report January 2022, Australian Energy Council C) Department of Industry, Science, Energy and Resources (2020). Australian Energy Update

Virtual Power Plants (VPP)

Virtual power plants (VPP) make use of renewable energy by using technology to provide energy to the grid during peak times, reducing pressure and increasing efficiency. In Australia, VPP offers have been developed by a mix of energy retailers, government bodies, and manufacturers offering incentives and cash rebates to join

VPP operators earn revenue by participating in the NEM

One South Australian VPP, designed and developed by Tesla and funded by the CEFC and ARENA, aims to by the world's largest VPP with over 50,000 installations[1]

AEMO expects VPPs to add significant controllable demand across the NEM as demand-side participation is forecast to double by 2040[2]

Batteries include Duracell, SolaX, Tesla, Redback, Eveready, Hive, AlphaESS

Subsidies / incentives can include a high feed-in tariff, joining credit and battery subsidies

Case study: "Batteries on poles" trial[3]

- Trial by Thycon and United Energy
- Custom-built batteries will be mounted on electricity poles
- Fleet of 40 batteries, each of 30 kW / 66 kWh (2 hour duration) and 1 m x 2 m
- Simply Energy will lease the batteries' capacity during troughs
- Simply will also use the batteries for its own VPP programme
- ARENA will provide $4 million funding, with United to provide the remaining 6.98 million

Source: 1. 'South Australia's Virtual Power Plant' , South Australia Department of Energy and Mining (2020) 2. 2020 Integrated System Plan, *AEMO* (July 2020). 3. 'Transforming the grid with pole-mounted batteries' (August 2022) *Department of Industry, Science, Energy & Resources*

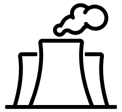
GAS NETWORKS IN AUSTRALIA

Future of reticulated gas consumption in Australia

Current Scenario

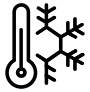
> 5 Million

More than 5 million Australian homes and businesses are connected to gas[2]



26%

Natural gas provides about 26% of energy consumed in Australia[2]



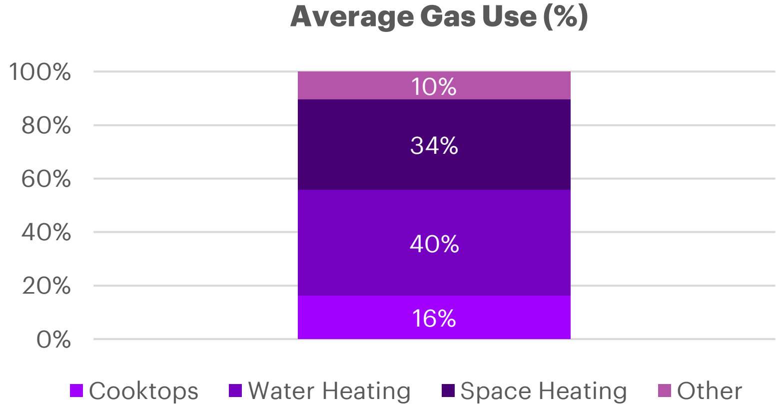
> 2x

During winter, gas provides more than double the energy of electricity for residential homes[2]

Gas contributes to many parts of Australia's economy and provides energy to households, businesses and industrial processes. Its main roles vary by region as displayed in the table below.[3]

STATES	MAIN PURPOSE
VIC, NSW, ACT	Heating households during winter
SA, WA, NT	Power generation
QLD, NT, WA	Providing regional jobs and generating tax

On average, Australian households use gas more commonly for water heating (40%) and space heating (40%) whereas cooktops only account for 16% of total gas use.



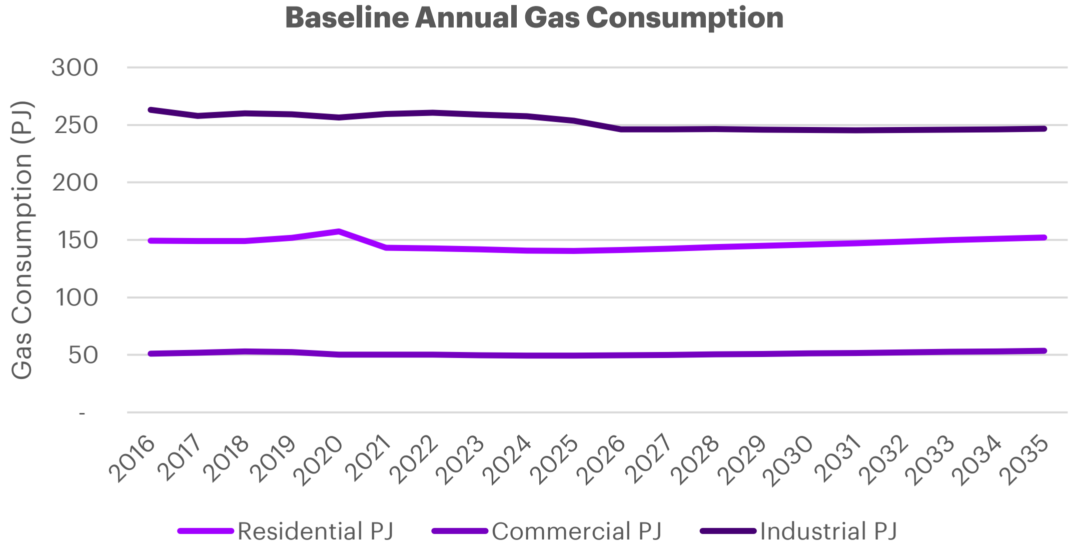
GAS USAGE OVER TIME

Industrial

Since 2016, industrial consumption displayed a slight decline over time. This is a result to the rising prices in gas over the years. Other factors such as labour costs, international competition and local demand could have contributed to this decline.

Residential & Commercial

Due to cooler seasons in 2020, Residential gas consumption increased by approximately 3% from 2019. The graph below forecasts a relatively stable level of gas consumption in the residential and commercial sector. However, both commercial and residential gas consumption is expected to decline in the long-term due to a projected uptake in substituting gas appliances with electric.



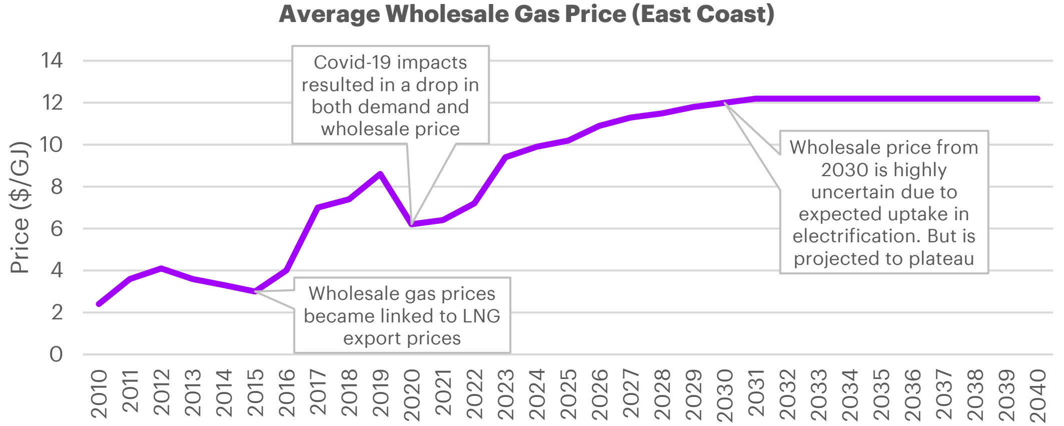
Sources: 1. Grattan Institute (2020), 2. Energy Networks Australia (2019), 3. Energy Networks Australia et al. (2020) 4. AEMO (2021)

GAS NETWORKS IN AUSTRALIA

Future of reticulated gas consumption in Australia

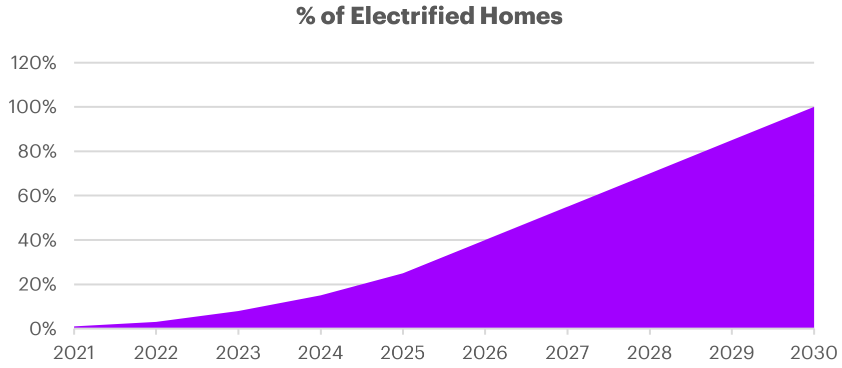
Forecasted Gas Prices

Wholesale gas prices along the east coast remained relatively low until 2015. In 2020, prices declined by about 40% from 2019 to approximately $6/GJ, due to covid-19 decreasing the demand. Prices are expected to increase from 2022 onwards due to the price association with LNG prices. From 2031 onwards, the price is projected to flatten due to the supply/demand balance.[1] (Approximate values were calculated from this report)



Forecasted Growth of Electrified Homes

If 3% of homes are electrified starting from 2022, and reaching 40% by 2026, achieving 100% of electrified Australian households by 2030 is possible.[4] However, the scale and upfront financial implications of this transition on consumers will be large. Governments will have a crucial role in managing affordability and equity issues associated with the transition away from gas.



DISTRIBUTION NETWORK VALUATIONS

Overview

4.3MIL

Australian gas distribution pipelines supply gas to 4.3million households and 130,000 commercial and industry users

90,420km

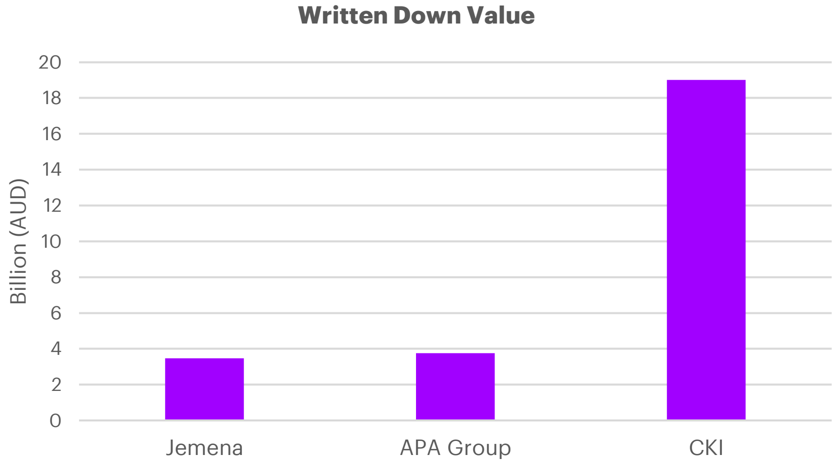
The total length of the Australian gas distribution networks is a total of 90,420. Which has expanded by approximately 10% since 2009

$8BIL

The networks deliver over 370PJ of gas per year and has a regulated asset value of $8 billion

Australian gas pipelines are all privately owned. The **APA group** is Australia's largest gas pipeline business with a **$22 billion** portfolio mainly of gas pipelines and distribution infrastructure. Other sector participants include **Jemena Gas Networks** (owned by State Grid Corporation of China and Singapore Power International) which manages more than $**8.5 billion** worth of Australia utility assets. **Cheung Kong Infrastructure (CKI) Holdings Limited** operates Australian Gas Networks have an asset value of **$15 million (HKD).**[5]

Written down value[6]



Sources: 1. Core & Energy Resources (2019), 2. IBISWorld (2022)
3. Renew Economy (2020) 4. Rewiring Australia (2022) 5. CKI (2020) 6. Jemena (2020), APA (2020), Finbox (2022)