# Clean Energy Clean Demand

Enabling a zero emissions energy system with energy management, renewables and electrification

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# Acknowledgements


The energy sector has undergone dramatic changes in the past decade. As a result, many people have asked me what the rapid rise in low-cost renewable energy and electrification mean for energy efficiency. This excellent question led to the development of this report.

*Clean Energy, Clean Demand* covers a wide range of issues and would not have been possible without the work of many people. I would like to thank the experts who published critical papers, spoke to me at length or reviewed drafts of this report. While these experts' input was essential, any errors are mine alone and contributors were not asked to endorse my conclusions. There are too many people whose work impacted on this report to name them all, but I would like to especially thank the following individuals:

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# About the EEC

EEC is the peak body for Australia's energy management sector.

We are a membership association for businesses, universities, governments and NGOs that have come together to ensure Australia harnesses the power of efficiency, electrification and demand management to deliver a prosperous, equitable, net zero Australia with:

- People living and working in healthy, comfortable buildings;
- Businesses thriving in a decarbonised global economy; and
- An energy system delivering affordable, reliable energy to everyone.

EEC works on behalf of its members to drive world-leading government policy, support businesses to rapidly decarbonise, and to ensure we have the skilled professionals to drive Australia's energy transformation.

EEC would not be able to deliver reports like this without the support of our members. In particular we'd like to thank our Industry Leader members:

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# Key terms

**Smart energy use, demand management** and **energy management** mean any form of managing the time and/or volume of energy use, including energy efficiency, load shifting and demand response.

**Demand response** means changing when we use energy use in response to conditions in the grid. For example, a refrigerated warehouse could briefly reduce its energy use when there are constraints in energy supply.

**Domestic** in this report refers to activities that occur in Australia, rather than in a house. For example, 'domestic energy consumption' refers to the amount of energy consumed in Australia.

**Energy conservation** means using less of an energy service (e.g. heating). Energy conservation can be valuable in an emergency (see section 2.4). However, if it is encouraged in the wrong situations it can result in a loss of comfort and productivity. Energy conservation is very different to energy efficiency.

**Energy drought** means a period of limited sunshine and wind when much less energy is generated by solar panels and wind generators. Energy droughts are sometimes called 'dankelflaute', the German word for 'dark doldrum'. Energy droughts are not per se a problem – the issue is when energy droughts coincide with periods of solid demand for electricity, which we call 'pinch points'.

**Energy efficiency** means getting more output or service from each unit of energy – or using less energy to achieve the same output. For example, a modern light-emitting diode (LED) light bulb can deliver the same light as an incandescent light bulb while using 90 per cent less electricity. Energy efficiency improvement can deliver multiple benefits, including lower energy bills, reduced greenhouse gas emissions and healthier homes.

**Energy productivity** means gaining more value from each unit of primary energy consumed. For example, reducing rejects due to faults on a production line can increase profits without changing energy use. At a national level it is generally measured in Gross Domestic Product per unit of energy consumed.

**Energy service** is the name for any service that uses energy as an input. Examples of energy services include: comfortable homes; hot water; and the transformation of aluminium oxide into aluminium.

**Final energy consumption** is the total energy consumed by end users, such as households and manufacturing, and excludes the energy used by the energy sector (e.g. it ignores the energy lost to the atmosphere when coals is burnt to generate electricity).

**Firmed renewables** means a combination of renewable generation, storage and network investment to ensure that supply and demand match. It is important to note that 'firmed renewables' does not mean we should aim for renewable plants that mimic thermal generation – instead it means a combination of thousands of investments that deliver reliable energy supply.

**Load shifting** means adjusting the timing of energy use to better align with renewable generation. Load shifting can be very dynamic, such as shifting energy demand on a very hot day, or permanent, such as always running water heaters in the middle of the day.

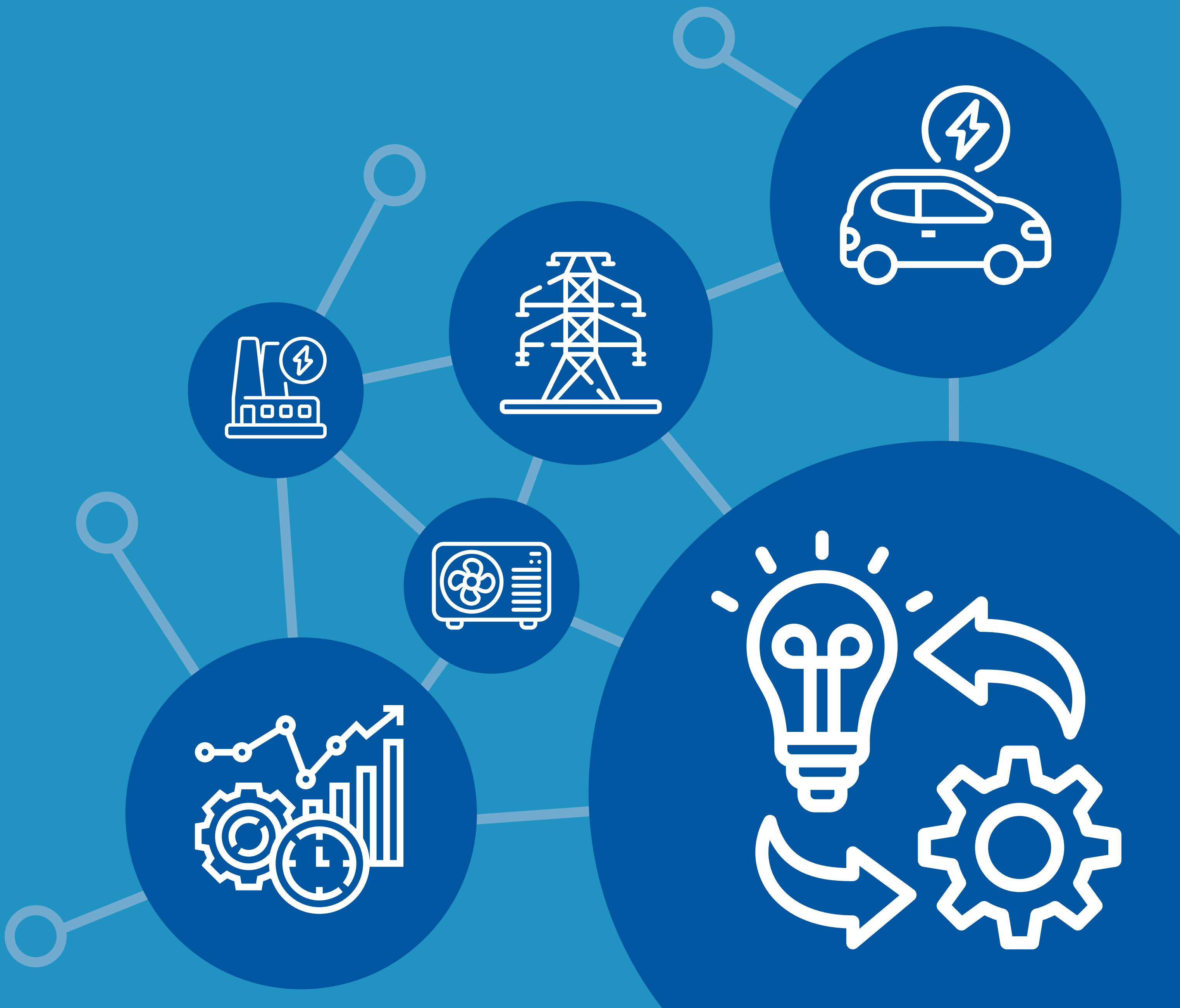
**Co-benefits** are benefits beyond savings on energy resulting from energy efficiency improvement. They may be financial, social or environmental. For example improved service quality such as health, improved product quality and reduced maintenance costs.

**Oversizing** means constructing renewable generation so its annual output is higher than annual demand for electricity. An oversized system may still produce less electricity than is required to meet demand during every minute of the year.

**Pinch point** is a period when energy available from generation and storage are close to, or lower than, demand.

**Spilling** is the process of not using all the output of renewable generation. For example, a solar panel on an off-grid home that generates more energy on a spring day than the house can use or stores, would 'spill' its excess generation. Some level of spilling is natural and inevitable in a renewable energy system.

# 01 Executive summary



Australia's energy systems are undergoing a profound transformation. Global factors have dramatically increased prices for gas, coal, oil and electricity. These factors are interacting with local issues, such as the declining reliability of coal fired generators, to raise domestic energy prices. A rapid shift to renewable generation offers the promise of cleaner and more affordable electricity, but the transition to variable renewables is uncharted and complex.

To address these challenges, we need substantial investment in renewable generation, storage, transmission networks, electrification and renewable fuels. However, if we don't complement these investments with energy management, the shift to clean energy will be slower, more expensive and runs the risk of reducing reliability.

'Energy management' is a broad term that includes:

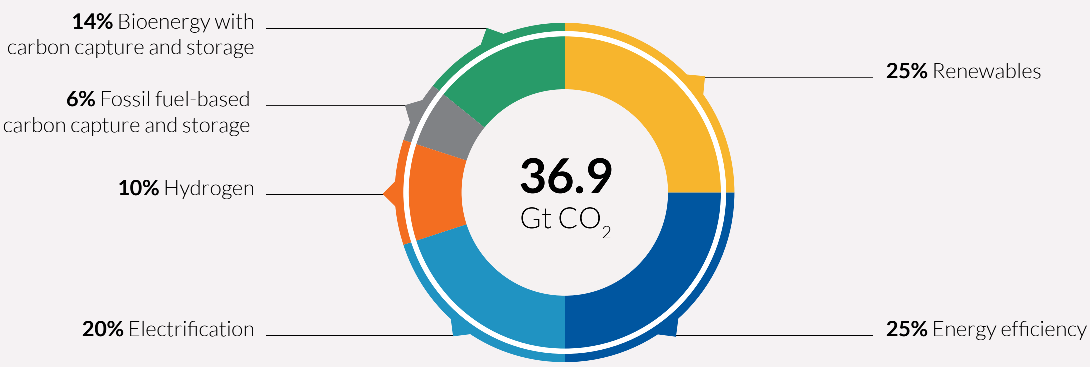
- **Energy efficiency:** Using less energy to achieve the same or better outcomes, such as using efficient appliances, insulation and draught proofing to keep our homes affordably warm in winter and cool in summer;
- **Load-shifting:** Timing energy use to better align with renewable generation, such as running water heaters in the middle of the day; and
- **Demand response:** Adjusting energy use when necessary to benefit our energy system, such as timing when compressors run in refrigerated warehouses to avoid using electricity when it is expensive.

The role of energy management is changing. In the past, saving energy at any time delivered both emissions reductions and cost savings. In the future, *when* we save energy will have a major effect on its value. For example, saving energy in winter, when solar panels aren't generating as much electricity, will generally reduce electricity costs and emissions far more than saving energy in spring.

**Historically, energy efficiency has been the single largest source of global greenhouse gas emissions reductions.[1] As recently as 2014 to 2016, energy efficiency accounted for more than 75 per cent of the stabilisation of global energy emissions.[2]**

Over the next two decades, smart energy use will continue to reduce emissions – the International Renewable Energy Agency (IRENA) estimates that energy efficiency will deliver 25 per cent of global abatement to 2050, the same amount they expect to come from renewable energy (Figure 1.1).

**Figure 1.1** Emissions reduction from the global energy sector to 2050




Source: IRENA 2022 *World Energy Transitions Outlook 2022: 1.5° C pathway*, IRENA, Abu Dhabi

1 Rosenow, J. and Eyre, N. 2022, "Reinventing energy efficiency for net zero", *Energy research and social science*, 90, 102602.

2 International Energy Agency 2017, *Energy Efficiency Market Report*, IEA, Paris.

Once electricity, gas and transport systems are *fully* decarbonised, energy management will not deliver further abatement. That does not mean its role will diminish. To ensure energy is both reliable and affordable, energy management will remain critical.

Wind and solar generation vary in their output. To ensure there is always sufficient electricity to meet demand, investments must be made in sufficient storage, generation and transmission to meet demand during critical periods, such as winter weeks with low wind and solar output. If electricity demand is reduced during these critical periods, the necessary spend on electricity supply infrastructure reduces with it. Managing demand is especially important in the next decade, when storage is likely to remain relatively expensive.

A key conclusion of this report is that – counter intuitively – an affordable renewable electricity grid will require both energy efficiency to minimise demand in lean periods, and the spilling of excess generation during periods of surplus production. While attempts should be made to find valuable uses for this surplus generation, a degree of spilling is inevitable. However, by maximising the use of renewable generation and reducing the extent that generation needs to be 'oversized' to ensure sufficient supply during critical demand periods, energy management can reduce spillage.

**The purpose of our electricity system is to meet people's demand for services such as comfortable homes and productive businesses. If we need less electricity to meet this demand, we will need to spend less on generation, storage and networks. This makes building a 100 per cent renewable grid faster, easier and cheaper.**

Energy efficiency will not only help keep energy systems affordable – it also helps minimise the risk that challenges in the roll out of generation, storage and transmission could significantly delay the energy transition. Managing demand will reduce the impacts of delays in projects or the development of new technologies.

Energy management is also critical to eliminate emissions from gas, petrol and diesel. Buildings and smaller vehicles are well-placed to electrify; while manufacturing, mining and larger vehicles will likely switch to a mix of electricity, biofuels, hydrogen and other renewable fuels. Electrification of the economy will be associated with a significant improvement in energy efficiency, as electric heat pumps and motors are far more energy efficient than their fossil-fuel counterparts.

However, electrification will still dramatically increase electricity consumption, particularly during winter, compounding the challenges and costs of transforming the electricity system.

Electrification must be introduced as efficiently as possible, with appliances and vehicles drawing from the grid at times which minimise load on the system. The potential variation between electrifying efficiently and inefficiently are clearly illustrated by the options to retrofit an existing home (Figure 1.2).

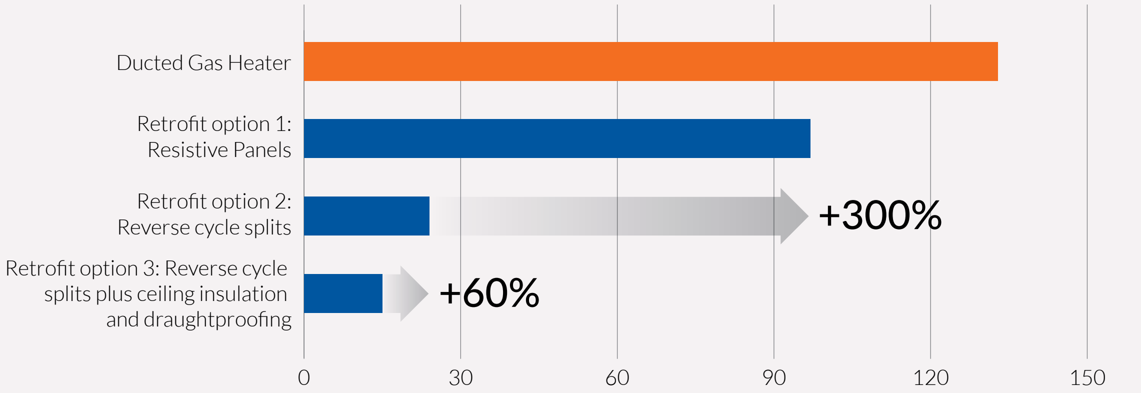
This chart highlights an important point. To communicate concepts to a wide audience, this report often refers to how households generate, store and use energy. However, its conclusions apply to both households and businesses. In fact, businesses and other institutions account for about two-thirds of Australia's energy use, and managing that use will be critical for both their competitiveness and Australia's energy future.[3]

Improving the energy management capabilities of businesses won't only reduce their energy bills, it will also improve overall business productivity, boost labour productivity and reduce materials waste. A 2013 study found that increasing Australia's energy efficiency by just one percentage point would raise per-capita gross domestic product by 2.26 per cent over 15 years, increasing real GDP by $25 billion.[4]

3 Derived from Department of Climate Change, Energy, the Environment and Water 2022, *Australian Energy Statistics 2022*, and DCCEEW 2022, *National inventory by economic sector*.

4 Vivid Economics 2013, *Energy efficiency and economic growth*, prepared for The Climate Institute, London, p.11.

**Figure 1.2** Energy required to heat an average Melbourne house on a winter's day (kWh)




Source: Modelling by Light House Architecture and Science, based on a real 160m² house built in the 1970s. The home had poor thermal efficiency, and a small investment in ceiling insulation and draughtproofing would more than double its NatHERS rating from 1.5 stars to 3.2 stars.

For both businesses and households, there are compelling reasons to invest in energy management in buildings. Australian homes are too often unhealthy and uncomfortable because they are draughty and poorly insulated. Upgrading them would save lives and reduce the cost of our health system.[5] The health and productivity improvements brought by investment in energy management are equally important in the workplace,[6] and have been ignored for too long.

The Australian energy sector has traditionally treated energy demand as fixed and immutable, and considered demand separately to supply. Increasingly, experts are recognising the real choices about how energy is used. Thinking about supply and demand together is critical for the future of the energy system.

Smarter energy use isn't a sacrifice – it will deliver better homes and businesses while cutting energy bills and emissions.

> "…energy efficiency action is the unambiguous first and best response to simultaneously meet affordability, supply security and climate goals."[7]

**International Energy Agency (IEA), 2022**

5 Sustainability Victoria 2022, *The Victorian Healthy Homes Program Research findings.*

6 IEA 2019, 'Health and well-being', *Multiple benefits of energy efficiency: from "hidden fuel" to "first fuel".*

7 International Energy Agency 2022, *Energy Efficiency 2022*, IEA, Paris.

## Key findings

### A Managing demand – as well as supply – is critical for a fast, reliable and affordable energy transition

Australia's electricity system must deliver reliable, affordable energy while rapidly reducing emissions to near-zero. This challenge cannot be underestimated. As investments are made in generation, storage and networks, demand management will make transforming the energy system easier, faster and more affordable.

### B Electrifying efficiently will support the rapid, affordable decarbonisation of electricity

To decarbonise at the rate required over the next decade, a huge amount of Australia's gas, petrol and diesel use will need to be electrified, especially in buildings and light transport. Electrifying loads efficiently and managing the demand placed on electricity grids will reduce the amount of supply-side infrastructure that needs to be built, accelerating decarbonisation while reducing costs.

### C Driving down the *total cost of our energy systems* will reduce bills for consumers

As Australia charts a path forward, focus should be placed on minimising the *total cost to society of providing energy services* through balanced investment across electricity generation, storage, networks, equipment and energy management. Reducing the amount consumers have to pay for energy services, such as warm homes and transport, is key.

### D Transforming energy demand requires urgent focus

Over the past two decades, substantial efforts have been made to transform Australia's energy supply, but far less effort has been put into how energy is used. Unlocking the potential of energy management to support the transition to net zero requires urgent action.

This report makes a number of high-level recommendations. More detailed recommendations are set out in previous EEC reports, such as the 2019 report, *The World's First Fuel*.[8]

8 Murray-Leach, R. 2019 *The World's First Fuel – how energy efficiency is reshaping global energy systems*, Energy Efficiency Council, Melbourne.

## Recommendations

### 1 Adopt the principle of 'least-cost energy services'

The goal of governments, market bodies and the energy sector should be to deliver affordable energy services to consumers by optimising investment across a combination of energy management, generation, storage, networks and appliances to reduce the total cost of the energy system. This means embedding the principle of 'least-cost energy services' throughout energy law and governance.

### 2 Reform energy market governance, rules and regulations

Numerous reviews of the National Electricity Market (NEM) and other jurisdictional energy markets have found a bias toward the supply-side.[9] While there have been some efforts to address this bias, fundamental problems remain. Correcting this requires enhanced governance, the creation of markets for demand-side services, and ensuring the demand-side is considered when developing measures such as capacity markets.

### 3 Build the capability to model and optimise demand- and supply-side measures

This report focuses on examining the changing role of energy management, and does not attempt the complex task of modelling the optimal mix of demand- and supply-side investments to deliver least-cost energy services. Australia needs to invest in detailed, granular and up-to-date data, and expand its capacity to model least-cost energy services, building on the people and systems that contributed to the Integrated System Plan (ISP).

### 4 Integrate supply-side and demand-side policy beyond energy markets

Energy markets are not the only drivers of investment in energy supply and energy management, and a diverse range of organisations work on issues such as minimum efficiency standards for appliances and buildings. Better coordination is required between these workstreams and energy markets, potentially including the establishment of a new national organisation to lead on energy management and integration of supply and demand.

### 5 Dramatically raise Australia's ambition on energy management and performance

Australia is currently ranked as the worst developed major energy user for energy efficiency policy and practice.[10] This lack of action has cost Australian homes and businesses billions of dollars and needlessly increased greenhouse gas emissions. As an innovative and advanced economy, the Australian government should aim to match other global leaders on energy management. Key actions include:

- Bring all existing homes up to at least a minimum standard of energy efficiency for heating, cooling and hot water. Improving the performance of our worst homes will not only deliver substantial cost savings, but even more substantial health benefits;
- Support businesses to adopt energy management systems and invest in the development and demonstration of key technologies for electrification and efficiency; and
- Set minimum energy efficiency standards for critical technologies. Millions of heat pumps and vehicles will be purchased in coming decades. Setting robust standards for this equipment will be critical to ensure Australia electrifies efficiently.

9 For example, Parer, W. 2002 *COAG Energy Market Review – Towards a Truly National and Efficient Energy Market*, Commonwealth of Australia, Canberra. p174.

10 American Council for an Energy Efficient Economy 2022 *International Energy Efficiency Scorecard 2022*, ACEEE, Washington DC.

# 02 Energy demand and smart energy use

## Summary

This chapter examines how energy is used in Australia today, and the available choices around how energy will be used in future. Defining key concepts up front will help to discuss more complex ideas later in the report.

## 2.1 Energy services and their impact on energy demand

Households and businesses don't directly consume electricity, gas, petrol and diesel. They use devices to convert fuels into useful *services*, e.g. light, warmth, and transport. Some major consumers of energy in Australia are:

- Cars and trucks, which use energy to move people and goods;
- Metals processing and manufacturing, such as aluminium refineries using electricity to convert aluminium oxide into aluminium;
- Non-metals manufacturing, such as ovens that use gas to bake bricks;
- Mining and milling, such as sites using energy to extract and grind rocks and transport ores; and
- Buildings, which mainly use energy for heating, cooling, hot water and appliances (Figure 2.1).

Devices can vary dramatically in the amount of energy they need to create an 'energy service.' For example, many light-emitting diode (LED) lightbulbs use 90 per cent less electricity to deliver the same amount of light as an incandescent lightbulb. Devices also vary in which fuels they consume, and this can impact their cost and efficiency. For example, electrical heat-pump space heaters can use less than 20 per cent of the energy required by gas space heaters to provide the same amount of warmth.[11]

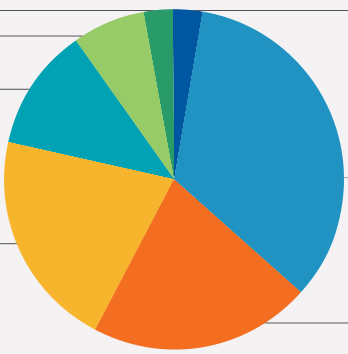
Energy services are often delivered by systems rather than single appliances. For example, a building that produces the service of a 'comfortable home' can involve: an appliance for heating and/or cooling; insulation; draught-proofing; and building design to optimise the impact of sunlight and cross-ventilation. The efficiency of a complex system can be improved by changing some or all of its parts.

People use equipment at different times, and this impacts *when* a building uses energy.

For example, in households:

- Fridges generally run constantly, with increases in electricity use after their doors have been opened and during warm weather;
- Space heaters are run in cold weather, usually during the morning and evening, although the time of day is changing as more people work from home;
- Ovens are typically used during weekday evenings and weekends; and
- Water heaters with storage tanks can run at night or in the daytime, even though most people take showers in the morning or evening (Figure 2.2).

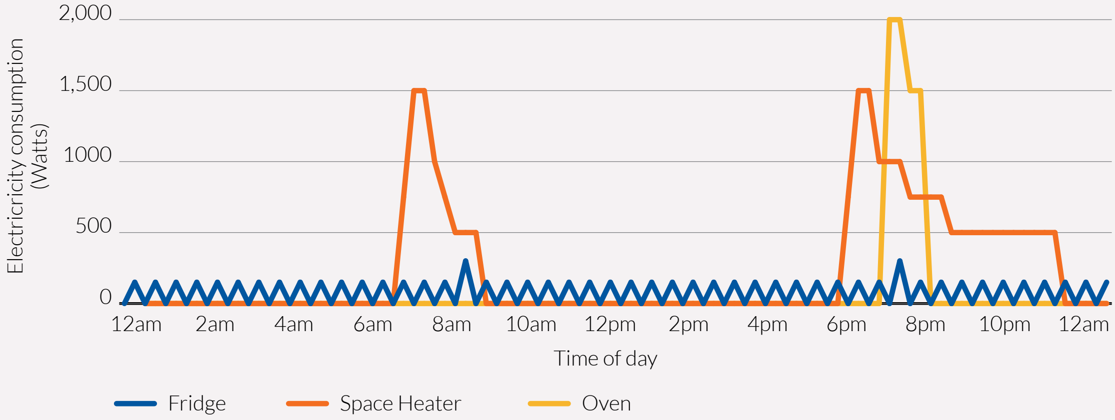
**Figure 2.1** Australian total final energy consumption by end use 2020-21




Source: Department of Climate Change, Energy, the Environment and Water 2022, *Australian Energy Update 2022*, Commonwealth Government, Canberra.

11 E3 Program *2021 Product profile – residential space heaters in Australia and New Zealand*, Australian Government Department of Industry, Science, Energy and Resources and the New South Wales Department of Planning, Industry and Environment.

**Figure 2.2** Illustrative electricity use profile for three devices in a home during a winter weekday




On commercial and industrial sites, equipment also varies in the volume and timing of energy use. For example, aluminium smelters can be very expensive to shut down, and generally operate 24 hours a day, seven days a week. In contrast, the lighting in offices largely runs during business hours.

As the cost of supplying energy varies by time, when equipment uses energy is important. For example, when solar panels are generating they provide relatively cheap electricity, which is beginning to lead to lower wholesale prices during daytimes than overnight (Figure 2.3). When the grid needs to rely on storage or more expensive forms of generation, such as gas and hydro, wholesale prices are higher. With the output of solar varying both across days and years, we can expect wholesale electricity prices will increasingly be higher overnight and during winter or rainy seasons (Figure 2.4).

The vast majority of homes and businesses are connected to electricity grids, adding an extra layer of complexity to the costs of energy services. The cost of building a grid is generally determined by the peak flow through the grid – this means the cost of building a grid is far more expensive if everyone draws electricity from it at the same time, rather than spreading their use out over time.

Currently, peak electricity demand generally occurs during heatwaves due to residential air conditioning, but this could change with greater penetration of technologies such as electric building heating, electric vehicles (EVs), solar panels, and storage.[12]

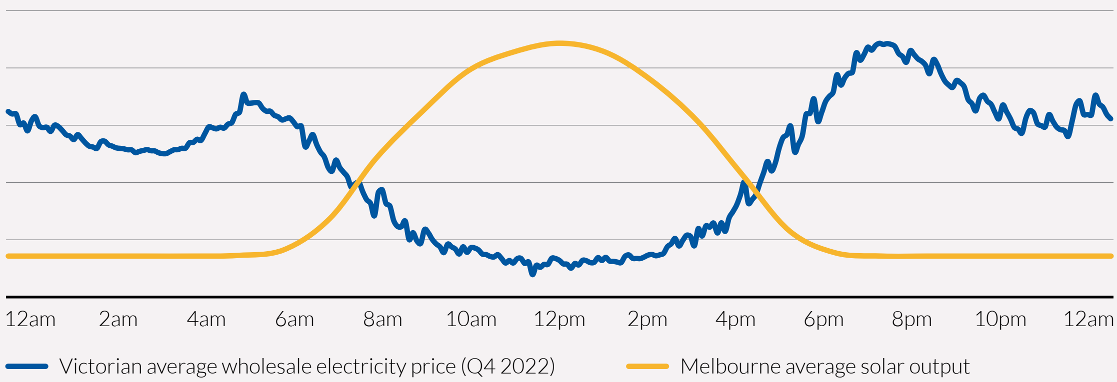
Where an energy user is located on the grid also impacts the cost of electricity. If a user charges their EV at home during the daytime from a solar system, the cost of transmitting that electricity to the car is extremely low.

If the same car is charged at an office without a solar system, costly electricity network infrastructure may be needed to transmit electricity to the car.

Being smarter about how much energy we use, and when and where we use it, will have a dramatic impact on energy costs. In the past, 'energy use' has often been treated as a fixed variable that is unable to be influenced. But as individuals, businesses and a society, we have a huge amount of control over how much energy we use and when we use it. The following sections provide an overview of the methods which enable energy use to be managed.

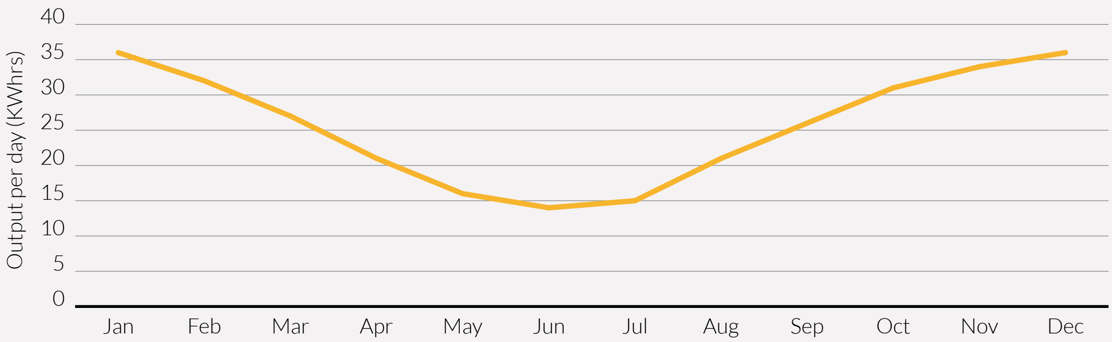
12 Australian Energy Market Operator 2022, *2022 Integrated System Plan*, AEMO Melbourne, p.51-52.

**Figure 2.3** Average actual solar weighted prices and solar exports across the day in Victoria




Source: Wholesale energy price from AEMO *2022 Quarterly Energy Demand databook*. Available online at https://aemo.com.au/-/media/files/major-publications/qed/2022/qed-q4-databook.xlsx?la=en&hash=040B80F41BAACEA91DD988774CCD7BAC

**Figure 2.4** Indicative daily output of a 6.6 kilowatt (kW) solar panel array in Sydney




Source: *https://solarcalculator.com.au/do-solar-panels-work-in-winter/*

## 2.2 Energy conservation

'Energy conservation' means consuming less of a service in order to save energy, such as driving less. Energy conservation can be valuable in emergencies, but if it is encouraged in the wrong situations it can result in a loss of comfort, wellbeing and productivity. Energy conservation is very different to energy efficiency, and it is not a focus of this report.

## 2.3 Energy efficiency

'Energy efficiency' means using less energy to deliver the same or better service. As noted earlier, LED lightbulbs typically use 90 per cent less energy to produce the same amount of light as incandescent lightbulbs. Many energy-efficient technologies are better than their alternatives in multiple ways – for example, quality LED lightbulbs produce less heat and better-quality light than older incandescent lightbulbs.

Energy efficiency means saving energy without sacrificing comfort or productivity. For example, 'energy conservation' in an office may mean switching off some lights, which will make the room dimmer. 'Energy efficiency' would mean installing lights that use less energy but are just as bright.

Different types of efficiency upgrades save energy at different times. To illustrate this, we can contrast energy efficiency in fridges and building heating. As mentioned, fridges run fairly constantly but use slightly more electricity after the door is opened and during warmer weather. This means replacing a fridge with a more efficient model will save a fairly consistent amount of electricity both over the course of a day, and over the course of a year (Figure 2.5).

In contrast, buildings in Australia's southern states run space heaters predominantly between April and October, and in homes, heaters largely run during mornings and evenings. This means improvements to heating efficiency, such as the installation of insulation and more efficient heaters, will predominantly save energy during winter (Figure 2.6). Upgrading the heating efficiency of buildings is particularly valuable as it saves electricity when solar panels are producing less electricity.

In other climate zones, trends are different. Electricity consumption in the Northern Territory's Darwin-Katherine Interconnected System is significantly higher during the wet season, around November to April, when the load from air-conditioning is highest and solar PV generation is lower. This makes actions that can reduce air-conditioning load in the wet season particularly valuable (Figure 2.7).

To date, energy efficiency has delivered huge benefits to Australia. On their own, minimum energy efficiency standards for appliances delivered between 9 and 15 per cent of Australia's national 2020 emissions reduction target, making them arguably Australia's most significant climate change program.[13] These standards are also estimated to have delivered savings equivalent to about 10 to 15 per cent of the average household's electricity bill, a total of between $9.4 and $18.8 billion in net benefits to consumers between 2000 and 2020.[14]

These figures represent a fraction of Australia's potential for energy efficiency– the IEA has found Australia has been improving its energy efficiency at a far lower rate than other developed countries.[15] In 2022, an independent think tank ranked Australia as the as the worst developed country for energy efficiency policy and practice out of the 25 largest energy-consuming countries in the world.[16] The good news is, this means Australia could save a huge amount of energy simply by adopting well-proven technologies, practices and policies from other countries.

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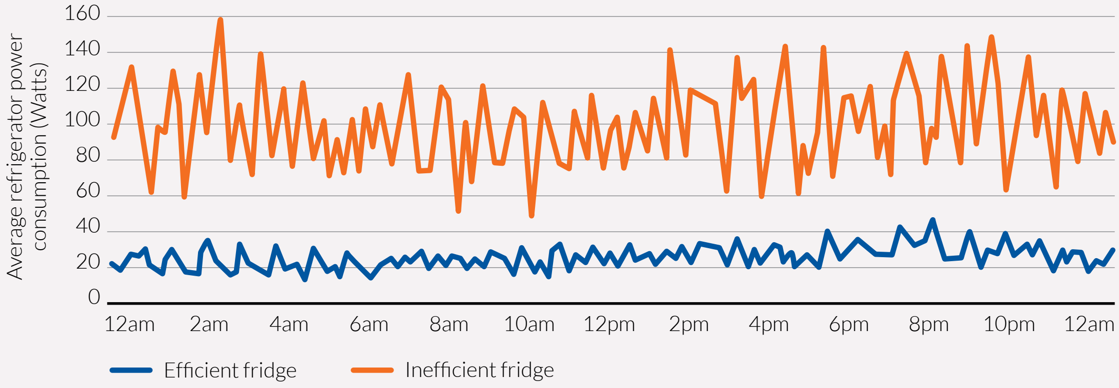
13 Department of the Environment and Energy 2018, *The Independent Review of the GEMS Act 2012 Draft Report*, Commonwealth of Australia, Canberra, p.29.

14 Department of the Environment and Energy 2018, *The Independent Review of the GEMS Act 2012 Draft Report*, Commonwealth of Australia, Canberra, p.29.

15 International Energy Agency 2017, *Energy Efficiency Market Report*, IEA, Paris, p22.

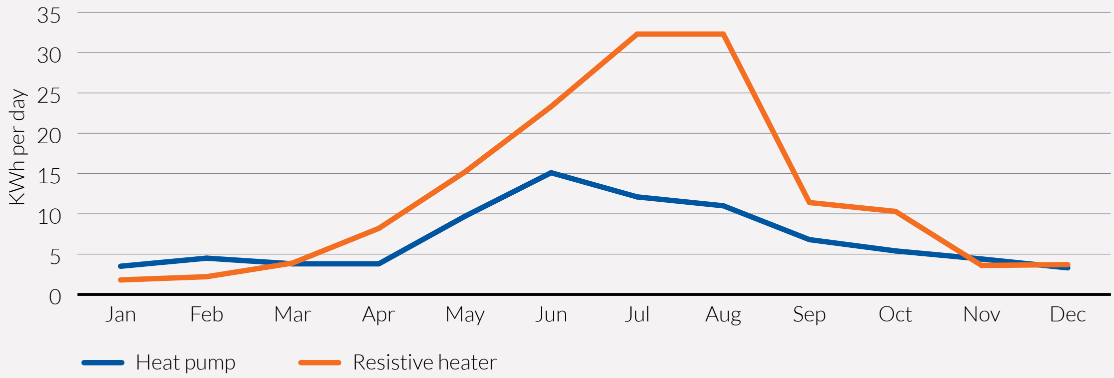
16 American Council for an Energy Efficient Economy 2022 *International Energy Efficiency Scorecard 2022*, ACEEE, Washington DC.

**Figure 2.5** Average daily load profile of an efficient and inefficient fridge



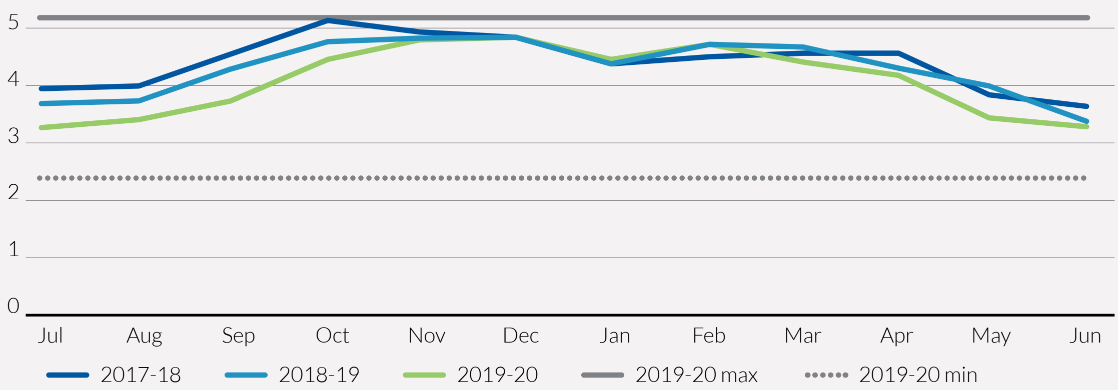

Source: Sustainability Victoria 2017 *Report on Refrigerator Retrofit trial*, Sustainability Victoria, Melbourne, Figure7.

**Figure 2.6** Example of the impact on a home's electricity consumption of replacing multiple electric resistive heaters with an electric heat-pump




Source: Author's own energy data, includes significant rebound effect.

**Figure 2.7** Average daily system consumption (GWh) in Darwin-Katherine Interconnected System




Source: Utilities Commission of the Northern Territory 2020, *Northern Territory Electricity Outlook Report*, Darwin, p.4

## 2.4 Electrification and energy efficiency

Some of the most substantial opportunities for Australia to improve its energy efficiency involve switching from equipment that uses gas, petrol and diesel to equipment that uses electricity. These opportunities include:

- **Heating homes and hot water:** Heat pumps can use less than a quarter of the energy that a gas-fired heater would use to supply the same amount of warmth;[17] and
- **Cars:** EVs typically use less than a third of the energy per kilometre required by Internal Combustion Engine Vehicles (ICEVs). While EVs convert over three-quarters of the energy they take from the grid into power at the wheels, internal combustion engine vehicles typically use only 12-30 per cent of the energy in their fuel, with the remainder being wasted.[18]

The huge increase in energy efficiency associated with these technologies means significant emissions savings, even if using electricity from gas-fired generators.[19] We will continue to stress the importance of electrifying efficiently to minimise the increase in electricity demand during critical periods. In Figure 2.6 both heating systems are electric, but one uses more than double the energy of the other. This is covered in more detail in Chapter 5.

## 2.5 Load flexibility and permanent load shaping

Equipment such as water heaters and EVs can be flexible when drawing electricity from the grid, making them able to use electricity when power is cheap and plentiful, lowering energy bills and reducing the total cost of the energy system.

Australia has a long history of adjusting loads to match generation. Coal-fired generators operate most efficiently when producing a fairly consistent amount of electricity, but demand for electricity tends to be much lower overnight. To address this, for decades electric storage water heaters have run at night to take advantage of excess electricity sold at cheaper 'off-peak' prices.

17 International Energy Agency 2022 *The Future of Heat Pumps*, IEA, Paris.

18 US Department of Energy 2022 *Fuel Economy – EV tech*, US Department of Energy, Washington. Accessed online on 24 August from https://www.fueleconomy.gov/feg/evtech.shtml

19 Smit, R. 2021 "A probabilistic life cycle assessment comparing greenhouse gas emissions from electric and fossil fuelled vehicles in Australia," *Air Quality and Climate Change Journal*, 55(1) 36-37.

**As our grid becomes more dominated by solar generation, it will make sense to run water heaters during the middle of the day, to take advantage of cheap solar.**

Devices vary in how flexible they are. Some loads:

- Are not flexible, such as lighting, which draws power when it is used;
- Can be put on a timer, such as water heaters in residential and commercial spaces. If loads are set to run at the same time each day, we refer to it as 'permanent load-shaping'; and
- Can vary when they run each day, such as cool-store warehouses and EV chargers. These devices can undertake permanent load shaping and also make *ad hoc* changes to their energy demand, which is called demand response. This is explained in more detail below.

Even for devices that are theoretically flexible in when and where they draw power, like EVs, the amount of flexibility can vary. If an EV is being used for a daily commute to an office, it might be able to be charged at home any time between 6pm and 7am or at the office between 9am and 5pm. However, if an EV is being driven from Melbourne to Sydney, a driver stopping into Albury to recharge their battery would want to charge it at a very specific time and location.

The flexibility of some loads can be increased. For example, in an uninsulated building the heating and cooling systems must be run when people are on site, so are relatively inflexible. But if a building is insulated, it could be 'pre-heated' or 'pre-cooled' during the daytime, before occupants arrive.[20]

## 2.6 Demand response

'Demand response' means changing when energy is used in response to conditions in the grid. On a very hot day when electricity becomes expensive in the afternoon, a refrigerated warehouse might run its cooling harder in the morning so it can run it less during the afternoon. Demand response can also involve *increasing* energy use at specific times – e.g. charging a battery when solar panels are producing more energy than the grid can accommodate.

Demand response is generally carried out to deliver four types of benefits to the energy user and/or the electricity system:

- **Wholesale energy prices:** An energy user can reduce their use of electricity when prices are high or increase their use of energy when prices are low. When an energy user shifts their demand away from high price periods, it not only lowers their own energy bill, it lowers the cost of electricity for all energy users.
- **Emergencies:** Sometimes energy is scarce due to a rare event, such as extreme weather, generator shut-downs or damage to the electrical grid. In these situations, energy users can be paid to reduce their non-essential energy use to preserve energy for more important uses.
- **Networks:** The cost of an electricity network is based on maximum demand on the network during peak periods. Shifting demand away from peak periods can reduce the amount of money needed to upgrade the network.
- **System stability:** The electricity grid needs to run at a frequency of 50 hertz (Hz). If there are rapid changes in supply or demand, demand response can be used to ensure the grid remains at 50 Hz. This is known as 'frequency control'.

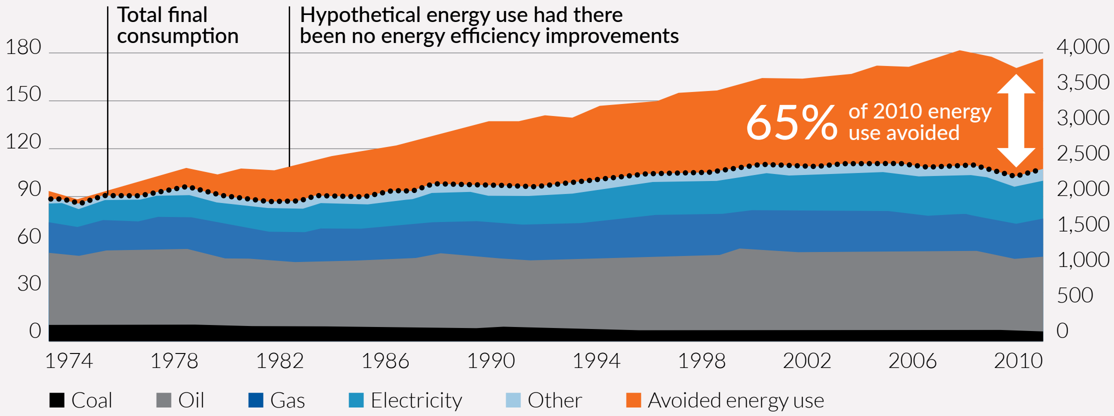
The volume of demand response potentially available in Australia is large, and could be much larger. Australian industry can provide at least 3.1 gigawatts of demand response, more than 150 per cent of the capacity of the Liddell coal-fired generator.[21] Demand response can generally provide capacity at much lower cost than generation. Until 2017, neither demand response nor batteries were allowed to participate in markets for 'Frequency Control and Ancillary Services' (FCAS). Allowing demand response and batteries to participate in these markets displaced more expensive sources of FCAS, contributing to the cost of FCAS falling by 57 per cent between the fourth quarter of 2017 and first quarter of 2018.[22]

20 Naderi S. et al 2022 "Consumer cost savings, improved thermal comfort, and reduced peak air conditioning demand through pre-cooling in Australian housing" *Energy and Buildings*, 271, 112172.

21 ClimateWorks Australia 2014, *Industrial Demand Side Response Potential*, ClimateWorks Australia, Melbourne.

22 Australian Energy Market Operator 2018 *Quarterly Energy Dynamics Q1 2018*, AEMO, Melbourne.

**Figure 2.8** Total avoided energy use from energy efficiency in 11 countries




Source: International Energy Agency 2013, Energy Efficiency Market Report, 2013, IEA, Paris.

## 2.7 Smart energy use as capacity

Reducing demand for energy can be regarded as a form of energy system 'capacity,' as it displaces the need for more expensive energy supply infrastructure, such as generators in the electricity system or oil rigs in petrol supply. Demand-side capacity is generally incredibly reliable – while a generator might fail, capacity created by replacing inefficient lights with LEDs can't simply be 'lost.'

In fact, energy efficiency is considered the single largest form of capacity in global energy systems, which is why the IEA calls it the 'first fuel'. Between 1974 and 2010, energy efficiency improvements in Australia and 10 other countries provided more capacity than any other fuel source, including electricity, coal and oil[23] (Figure 2.8).

Between 2000 and 2017, improvements in energy efficiency in the world's major economies reduced final energy consumption by 37 exajoules of energy – enough to meet both Japan's and India's energy needs[24].

In coming decades, the role of energy management in providing capacity for our electricity system will become increasingly important. Just like generation, different forms of energy management provide different types of capacity:

- **Baseload:** Australia's minimum energy efficiency standards for fridges and freezers have reduced energy demand by an estimated 360 megawatts (MW) at all times, eliminating the need to run a small coal fired generator 24 hours a day.[25]
- **Regular peaking:** Energy efficiency in heating and cooling buildings provides reliable capacity at very important times, when solar output is lower and networks are often constrained.
- **High-cost peaking:** Demand response tends to only be dispatched when energy prices are high, similar to open-cycle gas generation.
- **Reserve capacity:** Some forms of demand response, such as shutting down an industrial process, can be used in exceptional circumstances to prevent involuntary load-shedding among other energy users.

23 International Energy Agency 2013, *Energy Efficiency Market Report 2013*, IEA, Paris.
24 International Energy Agency 2018, *Energy Efficiency 2018*, IEA, Paris.
25 Department of Energy and Environment 2018, *The Independent Review of the GEMS Act 2012 Draft Report*, Commonwealth of Australia, Canberra.

**Australia's untapped potential for energy efficiency, load shifting and demand response could deliver a huge amount of reliable and low-cost capacity to the electricity system.**

## 2.8 Health and other drivers for energy management

Some actions that improve energy management also deliver other 'co-benefits', including improved health and productivity. While these co-benefits are not a focus of this report, they need to be factored into assessments of the costs and benefits of various energy management programs. Both the IEA and Energy Consumers Australia (ECA) have released guides on properly accounting for co-benefits in energy management.[26, 27]

Of particular importance, there are compelling reasons to retrofit older buildings in Australia to improve the health and wellbeing of Australians. Many older homes in Australia have poor energy efficiency – research in Victoria found a sample of homes built before 2005 had an average Nationwide House Energy Rating Scheme (NatHERS) rating of just 1.8 stars.[28] There are likely millions of dwellings in Australia that are draughty, poorly insulated and struggle to keep occupants cool in summer and warm in winter.

Hot and cold weather are estimated to be responsible for more than 3,000 deaths each year in Australia, and heatwaves have killed more Australians than any other natural disaster.[29, 30, 31] Upgrading older homes in Melbourne to a NatHERS energy efficiency rating of at least 5.4 stars could reduce deaths in an extreme heatwave by 90 per cent.[32] Upgrading our homes will also reduce deaths and illnesses attributed to cold weather. The poor quality of our building stock is likely to be a key factor in South Australia having a higher rate of death from hypothermia than Sweden.[33]

Multiple studies have found that upgrading the thermal performance of buildings can deliver benefit-cost ratios of up to 4:1, with health benefits accounting for around 75 per cent of the benefits.[34] An evaluation of the Victorian Healthy Homes program, which upgraded vulnerable Victorians' homes, has found that the program delivers about $10 in health benefits for every $1 in energy savings.[35]

Energy efficiency also delivers substantial productivity gains. A number of Australian and international studies have found close association between energy efficiency improvements in offices and worker productivity from fewer sick days, reduced stress and improved employee morale.[36] An independent review of the Commercial Building Disclosure (CBD) program found that retrofits resulting from the first years of the program delivered at least $168 million in improved occupant productivity, more than double the value of the energy savings.[37]

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26 ACIL Allen 2017 Multiple Impacts Framework – A report commissioned by Energy Consumers Australia, ACIL Allen, Melbourne.

27 IEA 2015 Capturing the multiple benefits of energy efficiency, IEA, Paris.

28 Sustainability Victoria 2015 *Energy Efficiency Upgrade Potential of Existing Victorian Houses*, Sustainability Victoria.

29 Gasparrini, A et al 2015, 'Mortality risk attributable to high and low ambient temperature: a multicountry observational study', *The Lancet*, vol. 386, no. 1991, pp. 367-375.

30 Longdon, T., Quilty, S. Haywood, P. Hunter, A. and Gruen, R. 2020 'Heat-related mortality: an urgent need to report and record', *The Lancet – Planetary Health*, 4(5) E171.

31 Coates, L., Haynes K., O'Brien J., McAneney J., Dimer de Oliveira, F. 2014 "Exploring 167 of vulnerability: An examination of extreme heat events in Australia 1844-2010," *Environmental Science and Policy*, 42 pages 33-44.

32 Alam, M. Rajeev, P. Sanjayan, J. and Zou, P. 2018 "Modelling the correlation between building energy ratings and heat-related mortality and morbidity," *Sustainable Cities and Society* 22 (2016) 29–39.

33 Bright, F. Winskog, C., Walker, M., and Byard, R. 2014 'A comparison of hypothermic deaths in South Australia and Sweden', *Journal of Forensic Science*, 59(4) 983-5.

34 IEA 2015 Capturing the multiple benefits of energy efficiency, IEA, Paris.

35 Sustainability Victoria 2022 *The Victorian Health Homes Program Research Findings*, Sustainability Victoria, Melbourne.

36 ACIL Allan 2016, *Commercial Building Disclosure Program Review – Final Report*, prepared for the Department of Industry and Science, ACIL Allan, Melbourne.

37 Ibid.

Similarly, multiple studies have found a relationship between improved energy efficiency and overall productivity in industry.[38] Improvements in energy efficiency are often associated with improved materials, staff and capital productivity and reduced operation and maintenance costs.[39]

**Improvements to health and productivity provide compelling reasons to invest in energy efficiency in buildings and businesses.**

Even in circumstances where energy costs are low, upgrading buildings and businesses would still make sense to capture the benefits to health and productivity that accrue from comfortable buildings and efficient businesses.

## 2.9 The rebound effect

The 'rebound effect' occurs when an improvement in energy efficiency results in an increased demand for services, resulting in less energy being saved than anticipated. For example, a household could respond to their home being insulated by increasing its temperature (as occurred in Figure 2.6), or a manufacturer responds to an improvement in plant efficiency by increasing production. In other words, the rebound effect is the result of energy users having a choice – whether to fully bank their energy savings or spend part of the savings on more services.

To understand the rebound effect, understanding the health and productivity benefits of energy management is critical. In residential heating, the rebound effect generally occurs when an occupant has been unable to afford heating their home to a desired temperature. Improving the energy efficiency of the home allows the occupant to raise the temperature closer to their preference.

As multiple studies suggest the health benefits from energy upgrades can be worth more than the energy savings, in residential heating the rebound effect can actually increase the net benefits of energy efficiency improvements.[40, 41] Likewise, if a business increases its production in response to energy efficiency reducing their energy bills, the rebound effect could be increasing the net benefits of the efficiency upgrade.

The size of the rebound effect needs to be considered when investments in energy savings are being counted on to deliver energy capacity or greenhouse gas emission reductions. Research on the rebound effect has found that rates vary between different circumstances, but are generally less than 30 per cent for household services.[42] In summary, the rebound effect is generally modest and can actually increase the overall benefits of investments in energy savings, but needs to be estimated and incorporated into the design of programs.

38 ClimateWorks Australia 2016 *Could boosting energy productivity improve your investor performance? A guide for investors*, ClimateWorks Australia, Melbourne.

39 International Energy Agency 2014 *Capturing the multiple benefits of energy efficiency*, IEA, Paris.

40 IEA 2015 Capturing the multiple benefits of energy efficiency, IEA, Paris.

41 Sustainability Victoria 2022 *The Victorian Health Homes Program Research Findings*, Sustainability Victoria, Melbourne.

42 Sorrel, S. Dimitropoulos, J. and Sommerville, M. 2009 "Empirical estimates of the direct rebound effect: A review," *Energy Policy* 37:4, Pages 1356-1371.

## 2.10 The changing role of energy management in emissions and affordability

In an energy system dominated by fossil fuels, every unit of energy saved delivers significant reductions in both energy costs and emissions.

### To date, energy efficiency has been the single largest source of greenhouse gas emissions reductions.[43]

Even as recently as 2014 to 2016, energy efficiency accounted for more than 75 per cent of the stabilisation of global energy emissions.[44]

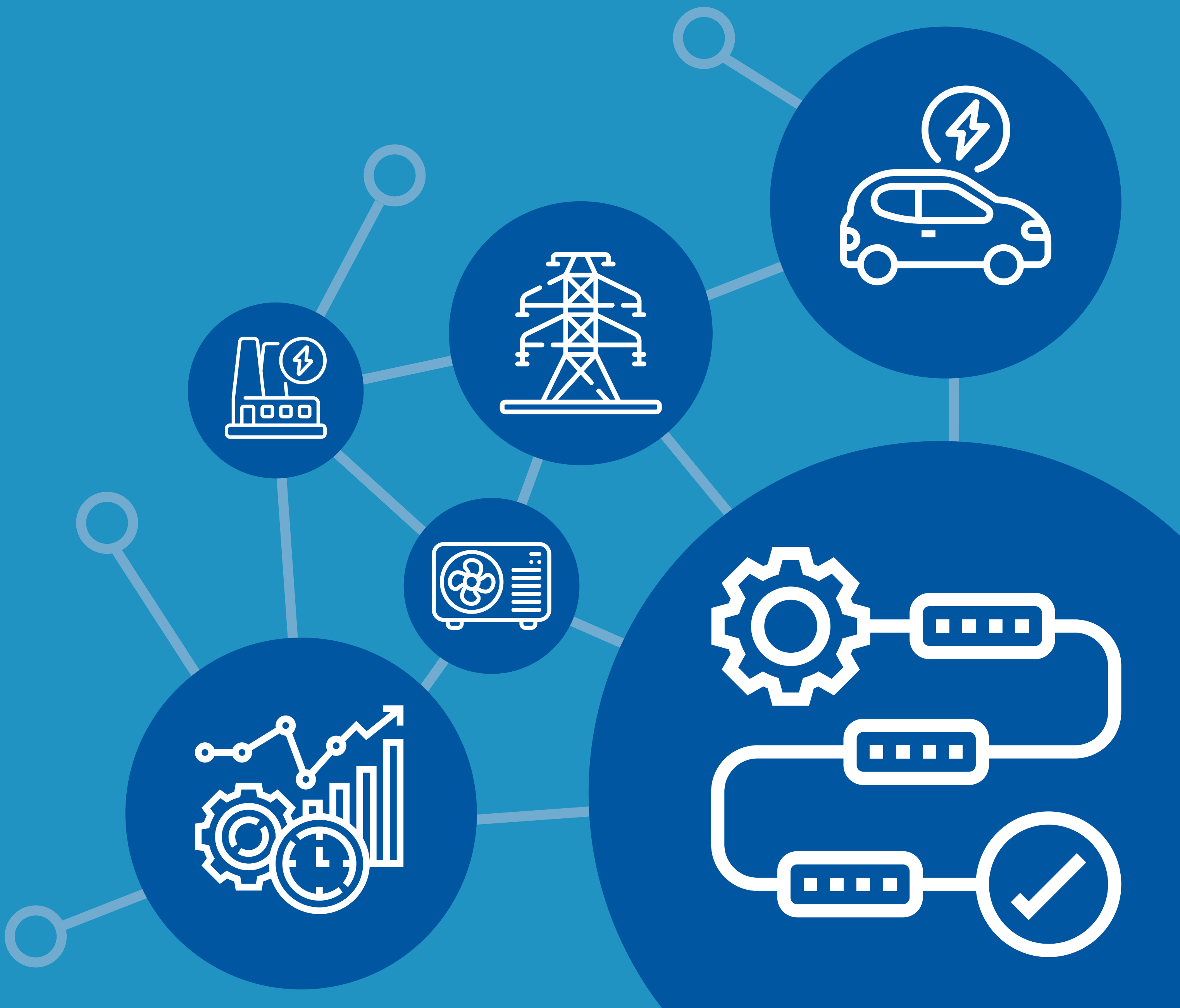
As energy systems decarbonise, energy management will play a critical but changing role.[45] This reports looks at the role of energy management in the current energy crisis (Chapter 3), the changing role of energy management in emissions reduction (Chapters 4 and 5), the changing role of energy management in energy affordability (Chapters 6 and 7) and the actions we need to take to unlock its potential (Chapter 8).

43 Lees, E. and Eyre, N. (2021). "Thirty years of climate mitigation: lessons from the 1989 options appraisal for the UK." *Energy Efficiency* 14(4): 37.

44 International Energy Agency 2017, *Energy Efficiency Market Report*, IEA, Paris.

45 Rosenow, J. and Eyre, N. 2022, "Reinventing energy efficiency for net zero", *Energy research and social science*, 90, 102602.

# 03 The energy crisis and energy management



## Summary

This chapter examines the causes of the current energy crisis and options to improve energy affordability. Investing in clean energy and energy efficiency will reduce Australia's vulnerability to fossil fuel price shocks.

## 3.1 The global energy crisis and its impact on Australia

In early 2022 the world entered an energy crisis. At that time Europe was dependent on Russia for around 40 per cent of the gas and 30 per cent of the oil it consumed.[46] Following Russia's invasion of Ukraine, many European leaders saw continued reliance on Russia for energy as a major risk, especially with regard to gas. Europe is currently attempting to permanently reduce its dependence on Russian gas partly through energy efficiency and electrification, but also by sourcing it from other global suppliers.

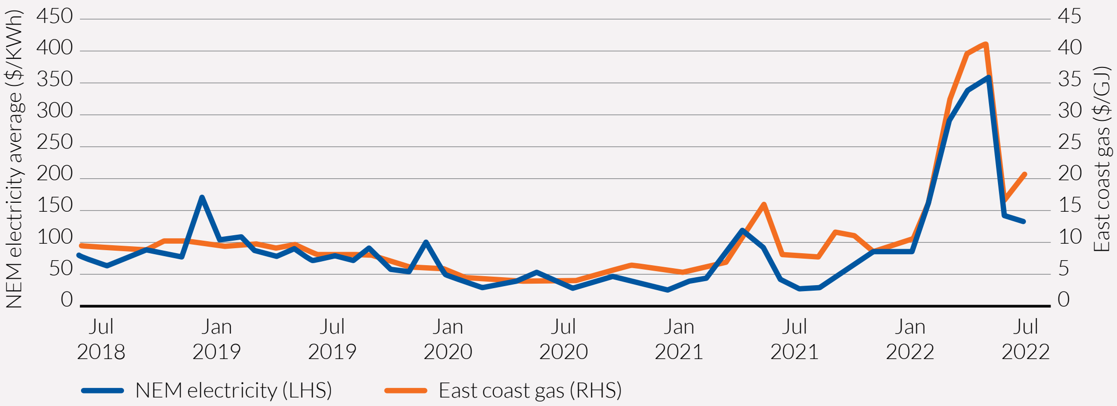
As Western nations increased the amount of oil and gas they sourced outside Russia, prices for those commodities increased. In turn, this elevated prices for both thermal coal and electricity.[47] While energy prices have moderated since their extraordinary peaks in 2022, in many countries they remain well above historic levels.

Australia has not been immune to this crisis. Australia produces a huge amount of gas, exporting 72 per cent.[48] Western Australia reserves 15 per cent of its gas production for local consumption, and so domestic gas prices remained moderate in that state.[49] On the east coast there is no reservation of gas for local consumption, which means domestic gas prices are strongly linked to international gas prices.

The spot price for gas across east coast markets averaged $28.40 per gigajoule (GJ) in the second quarter of 2022, 246 per cent higher than the previous year.[50]

The increase in gas prices has increased the cost of electricity generation on the east coast (Figure 3.1).

**Figure 3.1** East coast Australian electricity and gas prices




Source: Australian Energy Market Operator 2022 *Quarterly Energy Dynamics Q3 2022*, AEMO, Melbourne.

46 IEA 2022 *How Europe can cut natural gas imports from Russia significantly within a year.* Media release from 3 March 2022, accessed on 28 July 2022 from https://www.iea.org/news/how-europe-can-cut-natural-gas-imports-from-russia-significantly-within-a-year.

47 Australian Energy Regulator 2022, *State of the Energy Market 2022*, Australian Energy Regulator, Melbourne.

48 Department of Climate Change, Energy, the Environment and Water 2022, *Australian Energy Update 2022*, Commonwealth Government, Canberra.

49 Government of Western Australia 2021 WA Domestic Gas Policy, Government of Western Australia, Perth. Accessed online 2 March 2023 from https://www.wa.gov.au/government/publications/wa-domestic-gas-policy.

50 Australian Energy Market Operator 2022 *Quarterly Energy Dynamics Q2 2022*, AEMO, Melbourne.

However, electricity prices have also increased because of higher prices and lower volumes of coal-fired generation, which have been caused by both higher global thermal coal prices and the increasing unreliability of ageing coal-fired generators.[51]

The average wholesale electricity price in the NEM jumped to an extraordinary average of $264 per megawatt-hour (MWh) in the second quarter of 2022, more than triple the average price of the second quarter of the previous year.

While the average wholesale electricity price fell by 57 per cent between the second and fourth quarters of 2022, the price in the fourth quarter of 2022 was still 78 per cent higher than the fourth quarter of 2021.[52]

On 9 December 2022 the Australian Government announced a 12-month cap on wholesale gas contracts at $12 per Gigajoule (GJ), due to concerns that high gas and electricity prices would cause significant hardship for households and businesses. As a result, electricity futures prices fell significantly, but remained elevated over previous levels.[53] Furthermore, while $12 per GJ is substantially lower than the average wholesale gas price in the second and third quarters of 2022, it is still around three times the prices seen in the first decade of this century, and some large energy users have reported difficulties securing gas contracts.

The energy crisis is far from over and, even if prices return to their historic levels, it has demonstrated the vulnerability of Australia's current energy system to fossil fuel price shocks.

## 3.2 Supply-side options to address the energy crisis

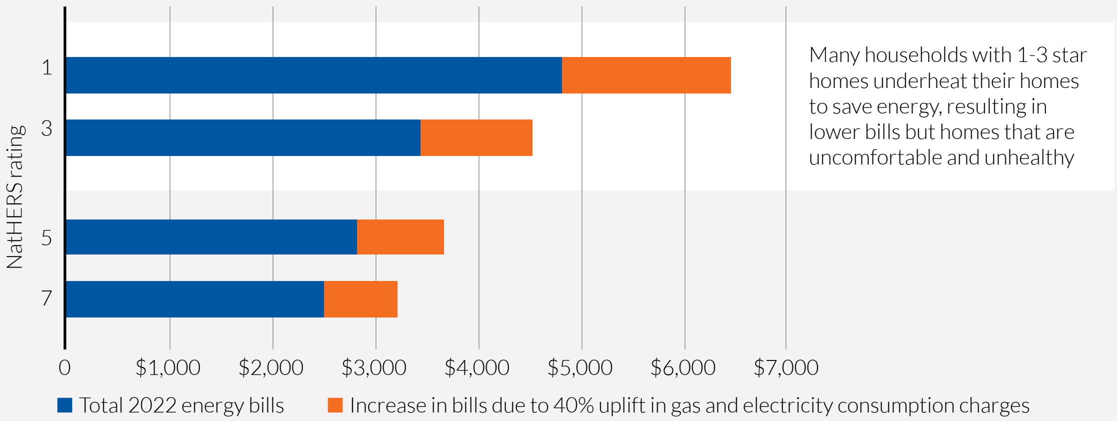
In the longer term, the construction of more renewable generation and storage should reduce Australia's exposure to global fossil-fuel price shocks and decrease the cost of electricity on the east coast. However, the construction of renewable generation and storage will take time and, as we explore in Chapter 6, while it will be substantially cheaper to invest in renewables than a new generation of coal-fired generators, there are still costs associated with the transition to clean energy.

51 Australian Energy Regulator 2022, *State of the Energy Market 2022*, Australian Energy Regulator, Melbourne.

52 Australian Energy Market Operator 2023 *Quarterly Energy Dynamics Q4 2022*, AEMO, Melbourne.

53 Ibid.

**Figure 3.2** The impact of building efficiency on annual household bills




Source: Modelling by Light House Architecture and Science. The modelling is based on a 160m$^2$ home in the Melbourne region, which uses gas ducted heating and electricity for all other energy services.

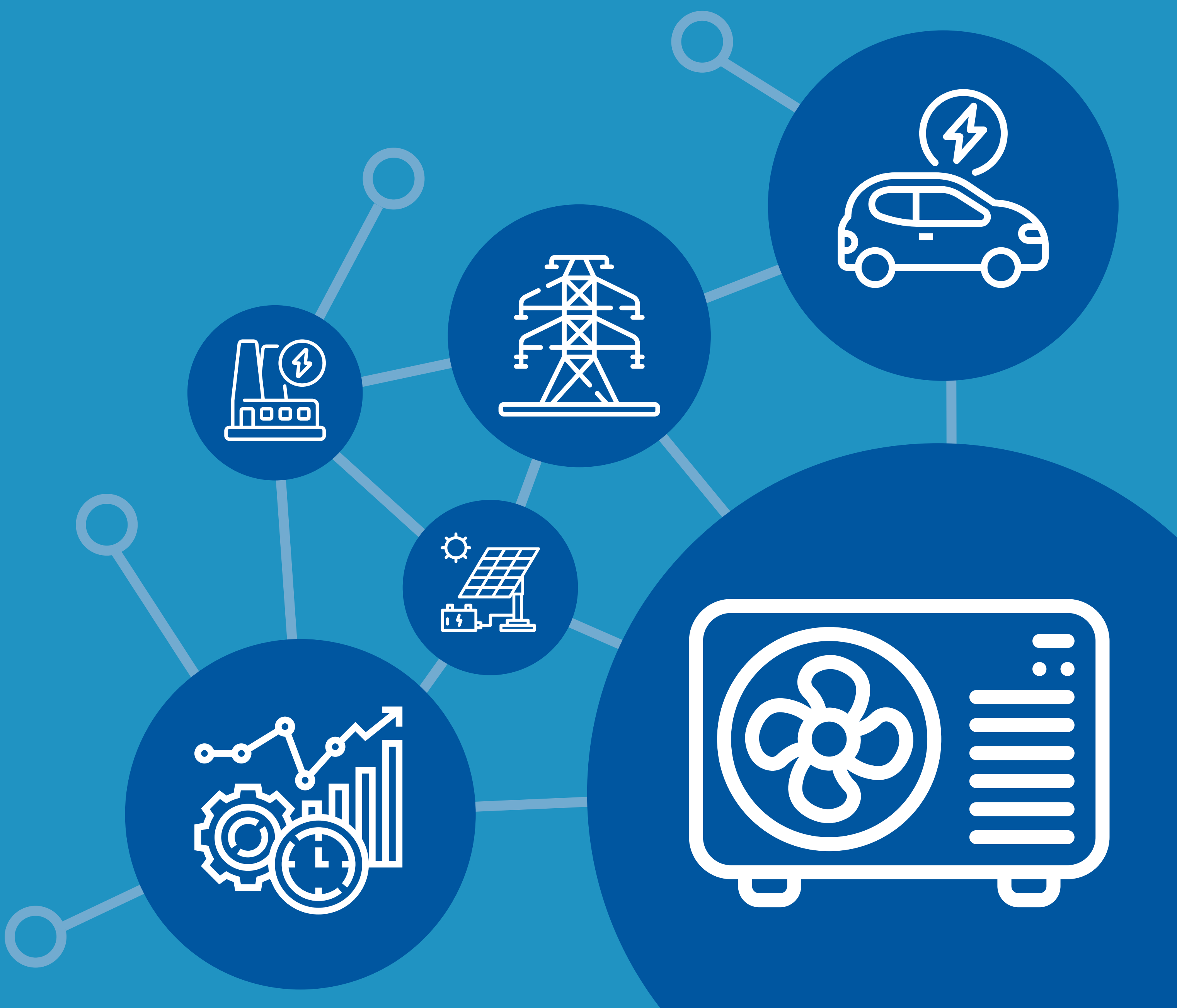
## 3.3 Energy management and the energy crisis

The current energy crisis is a crisis in the price of gas and wholesale electricity. This means the amount of gas and electricity a home or business uses will strongly affect the absolute size of their energy bills (Figure 3.2).

Improving the efficiency of a home or business not only decreases its energy bills, it also reduces its vulnerability to price shocks. For example, a 7-star home would only see energy bills rise by about $700 if gas and electricity consumption charges rose by 40 per cent, while a 1-star home would see its annual energy bills rise by over $1,600.

The inefficiency of many Australian homes and businesses leaves them highly vulnerable to rises in gas and electricity prices. Improving energy efficiency is critical to help them deal with the current price crisis, and insulate these homes and businesses against future volatility in fossil fuel prices. However, energy efficiency should be improved in ways that not only benefit households and businesses in the next decade, but also helps transition to a near zero electricity system. The changing role of energy management is explored in detail in Chapters 4 to 7.

# 04 | Reducing emissions from electricity



## Summary

This chapter examines how Australia's electricity sector is likely to change over coming decades, and the implications for energy management and greenhouse gas emissions. Reducing energy demand, especially at times when less energy is produced by renewable generators, will both reduce emissions and speed the transition to a renewables-led energy system.

## 4.1 Australia's emissions targets

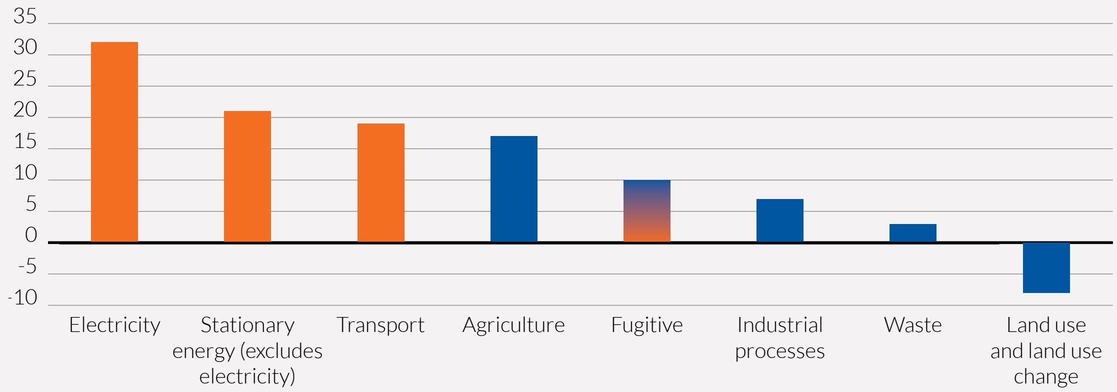
Australia has a bipartisan commitment to reduce its total emissions to 'net zero' by 2050. 'Net zero' acknowledges some parts of our economy will not be able to reduce their emissions to zero. These residual emissions will need to be offset by activities that remove greenhouse gases from the atmosphere such as carbon farming, which are sometimes called 'negative' emissions. However, there will only be a limited volume of these negative emissions available, and over time they are expected to become much more expensive. This means parts of the economy that *can* reduce their emissions to zero *should* do so.

The energy sector can and should aim to reduce its emissions to near-zero well before 2050. The energy sector includes electricity, stationary energy (excluding electricity) and transport, and accounts for over 70 per cent of Australia's emissions (Figure 4.1).

A further 10 per cent of our emissions come from fugitive gasses released during the extraction, processing and transport of fossil fuels.

Our climate is not impacted by emissions in a particular year, but by the cumulative volume of greenhouse gasses in the atmosphere. To limit climate change to 1.5 degrees of warming, the global community must minimise its cumulative emissions over the next 30 years. The figure below shows two potential emission-reduction trajectories – both end up at zero emissions by 2050, but the cumulative emissions from the fast trajectory are far lower. To minimise the impacts of dangerous climate change, we should aim for faster emission-reduction trajectories. Most modelling exercises have suggested that moving early to lower emissions is cheaper, as it involves a more gradual transition in the economy.[54] Conversely, delaying action can add substantial costs to the transition (Figure 4.2).[55]

**Figure 4.1** Australian emissions – share by sector for the year to September 2022

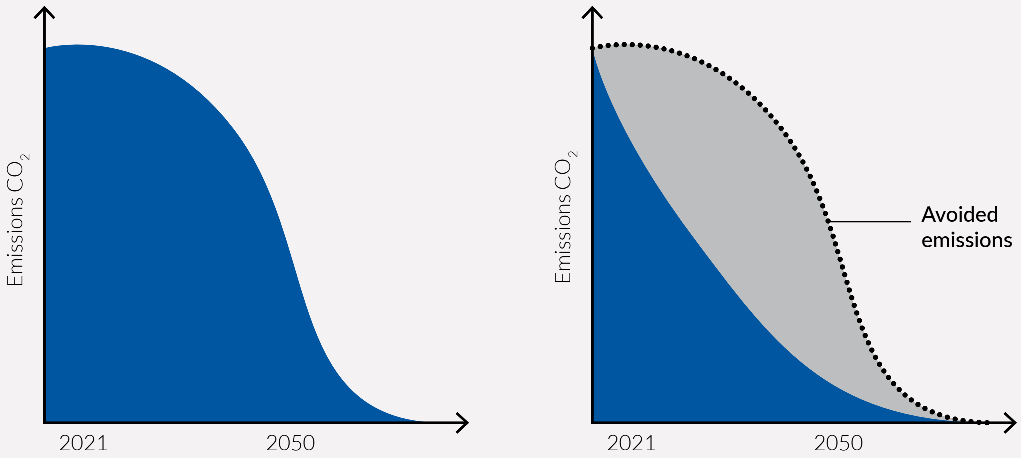



Source: Department of Climate Change, Energy, the Environment and Water 2023, Quarterly update of Australia's National Greenhouse Gas Inventory: September 2022, Commonwealth Government, Canberra.

54 Climate Change Authority 2014, *Targets and progress review*, Australian Government, Melbourne, p.121.

55 Sanderson, B and O'Neill, B, 2020, '[Assessing the costs of historical inaction on climate change](#)', *Scientific Reports*, v.10, p.9173.

**Figure 4.2** Indicative total emissions under two hypothetical emission-reduction trajectories




The Commonwealth Government has set a budget for cumulative emissions in the period 2021 to 2030 to be no more than 4,381 megatonnes of carbon dioxide equivalents ($MtCO_2$-e).[56] The Commonwealth Government has also legislated an interim emission reduction target to reduce Australia's emissions by 43 per cent below 2005 levels by 2030, and state and territory governments have set a variety of interim emission reduction targets. To achieve both our long-term, cumulative and interim emission reduction targets, emissions must be dramatically reduced in the energy sector over the next decade, and eliminated by 2050.

## 4.2 Emissions in the electricity sector

Australia's electricity sector is currently responsible for over 30 per cent of the country's emissions.[57] and must dramatically decarbonise by the mid 2030s for Australian jurisdictions to meet their emission reduction targets. [58] Australia has already begun to reduce its electricity emissions and there are good prospects for rapid decarbonisation.

Emissions from Australia's electricity sector have fallen around 20 per cent between 2005 and 2022 for two reasons.[59] First, electricity demand has been growing much slower than the economy (gross domestic product – GDP), for multiple reasons that include structural change in the economy and improvements in energy efficiency (Figure 4.3). Without this decline in the growth of demand for electricity, emissions in the electricity sector would be much higher.

Second, the proportion of electricity (MWh) coming from coal-fired generators dropped from 79 per cent to 53 per cent between 2005-06 and 2020-21, while the proportion of electricity coming from wind and solar has increased from about 1 per cent to 20 per cent over the same period (Figure 4.4).

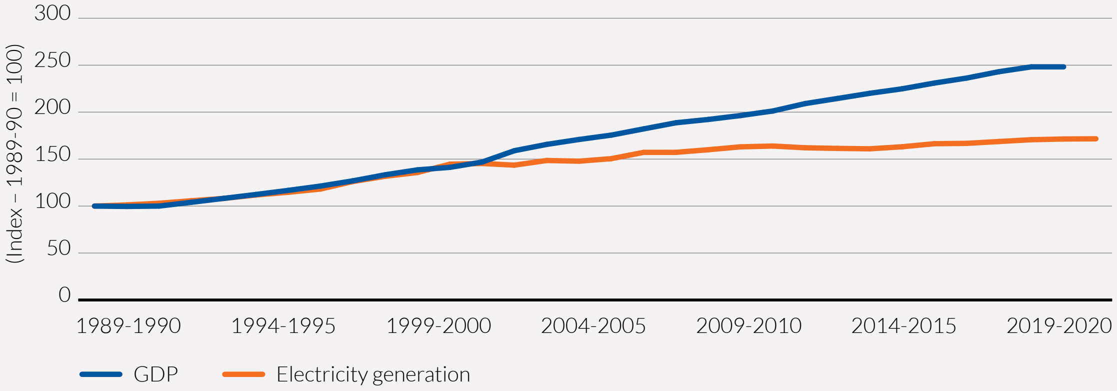
56 Department of Climate Change, Energy, the Environment and Water 2022 *Annual Climate Change Statement 2022*, Australian Government, Canberra.

57 Department of Climate Change, Energy, the Environment and Water 2022, *Quarterly update of Australia's National Greenhouse Gas Inventory: June 2022*, Commonwealth Government, Canberra.

58 Gilmore, J., Nelson, T., Nolan, T., 2022. *Firming technologies to reach 100% renewable energy production in Australia's National Electricity Market.. CAEEPR working paper*, Griffith University.

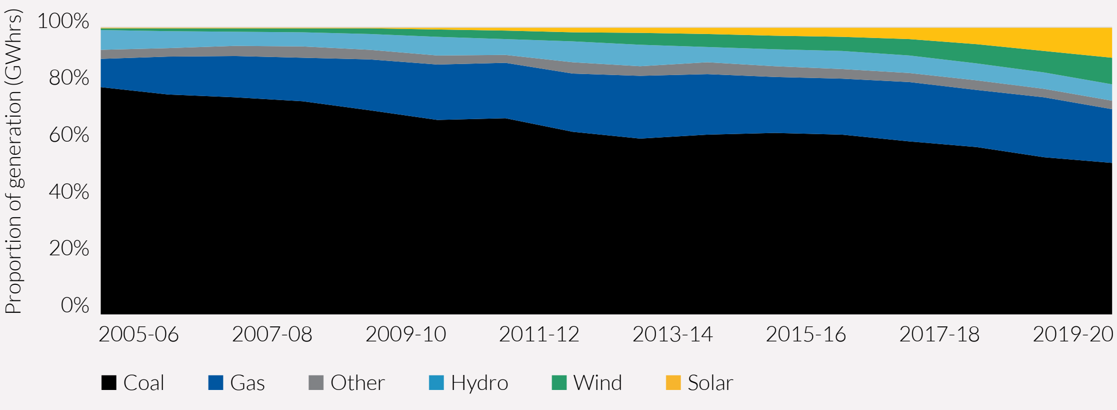
59 Department of Climate Change, Energy, the Environment and Water 2023, *Quarterly update of Australia's National Greenhouse Gas Inventory: September 2022*, Commonwealth Government, Canberra.

**Figure 4.3** Australian electricity generation and GDP growth




Source: Department of Climate Change, Energy, the Environment and Water 2022, Australian Energy Statistics – Tables B and O, Commonwealth Government, Canberra.

**Figure 4.4** The proportion of electricity generated by different fuels between 2005-06 and 2020-21




Source: Department of Climate Change, Energy, the Environment and Water 2022, *Australian Energy Statistics – Table O*, Commonwealth Government, Canberra.

Initially, Commonwealth, state and territory policies played a key role in driving the uptake of renewable energy in Australia. However, the cost of wind and solar generation have dropped dramatically, making them economically attractive even in the absence of government policies.

Wind and solar are now the cheapest sources of electricity per MWh generated, and their costs are projected to fall even further to 2040 (Figure 4.5).[60]

The Australian Energy Market Operator (AEMO) has engaged with a broad range of experts to develop scenarios for the future of the NEM. Energy industry stakeholders consider the Step Change scenario is most likely – a scenario where coal fired capacity closes relatively quickly and wind and solar rapidly become the dominant form of generation (Figure 4.6).[61]

The rate of transition in the electricity sector is far from assured. If renewables, storage and networks are not constructed fast enough to ensure demand is always met, coal and gas-fired generators will run for more hours, and be kept running for more years, delaying the fall in Australia's emissions. The issue of capacity is discussed in more detail in Chapter 6, but a key takeaway is that reducing demand for electricity at key times will reduce the need for supply, supporting the faster decline in Australia's electricity emissions.

## 4.3 The role of energy management in reducing electricity emissions

To date, energy efficiency has played a significant role in reducing greenhouse gas emissions associated with Australia's electricity sector. While generation was dominated by coal and gas, every kWh of electricity saved delivered significant emissions reductions.

Australia's electricity grids remain dominated by fossil fuels, and improving energy efficiency will continue delivering significant emission reductions for some time. As electricity grids decarbonise, energy efficiency's contribution to emissions reduction will evolve.[62] *When* energy is saved will increasingly impact on the amount of emissions avoided. Reducing demand when fossil-fuelled power stations are generating a large proportion of demand, such as winter evenings, will reduce emissions much more than reducing demand when renewable energy is generating a large proportion of electricity, such as midday in spring.

This means some forms of energy management will have disproportionately large impacts on emissions reductions. These include:

- Insulating a home, which will reduce peak demand in summer and winter evenings, when electricity generation is more likely to come from coal- and gas-fired generation;
- Load shifting commercial and residential water heaters into the middle of the day, to take advantage of the output of peak solar production; and
- Timing the energy-intensive industrial processes that have a degree of flexibility, so they predominantly run during daylight hours.

To minimise cumulative emissions, we should take every opportunity to lock in early, cost effective emission reductions, as these will deliver abatement over many years. While electricity production will eventually become zero-emissions, it is crucial we don't ignore opportunities to reduce our consumption of emissions-intensive electricity today.

60 Graham, P., Hayward, J., Foster J. and Havas, L. 2022, *GenCost 2021-22: Final report*, CSIRO, Canberra.

61 Australian Energy Market Operator 2022 *Integrated System Plan – June 2022*, AEMO, Melbourne, p9 Figure 1.

62 Rosenow, J. and Eyre, N. 2022, "Reinventing energy efficiency for net zero", *Energy research and social science*, 90, 102602.

**Figure 4.5** Calculated levelised costs of energy in 2021-22

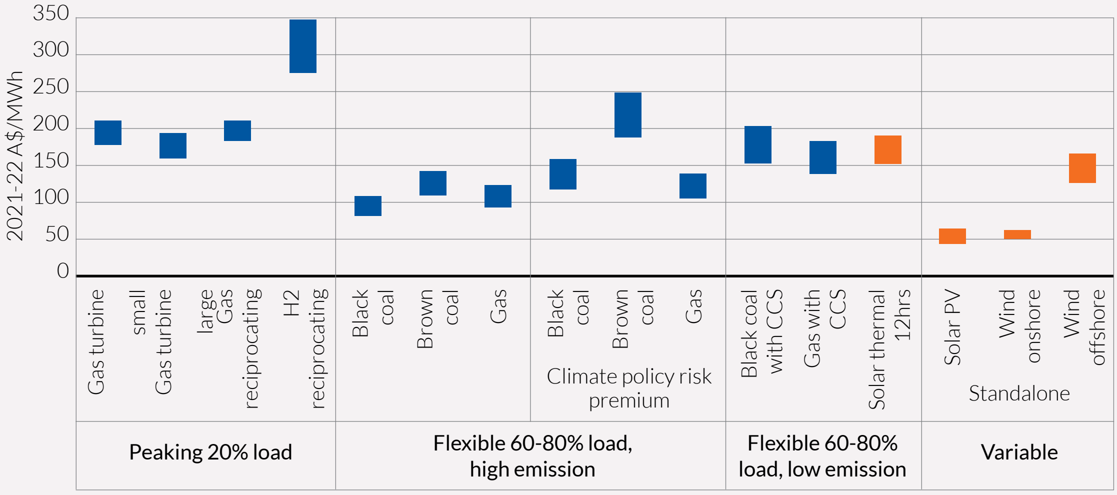
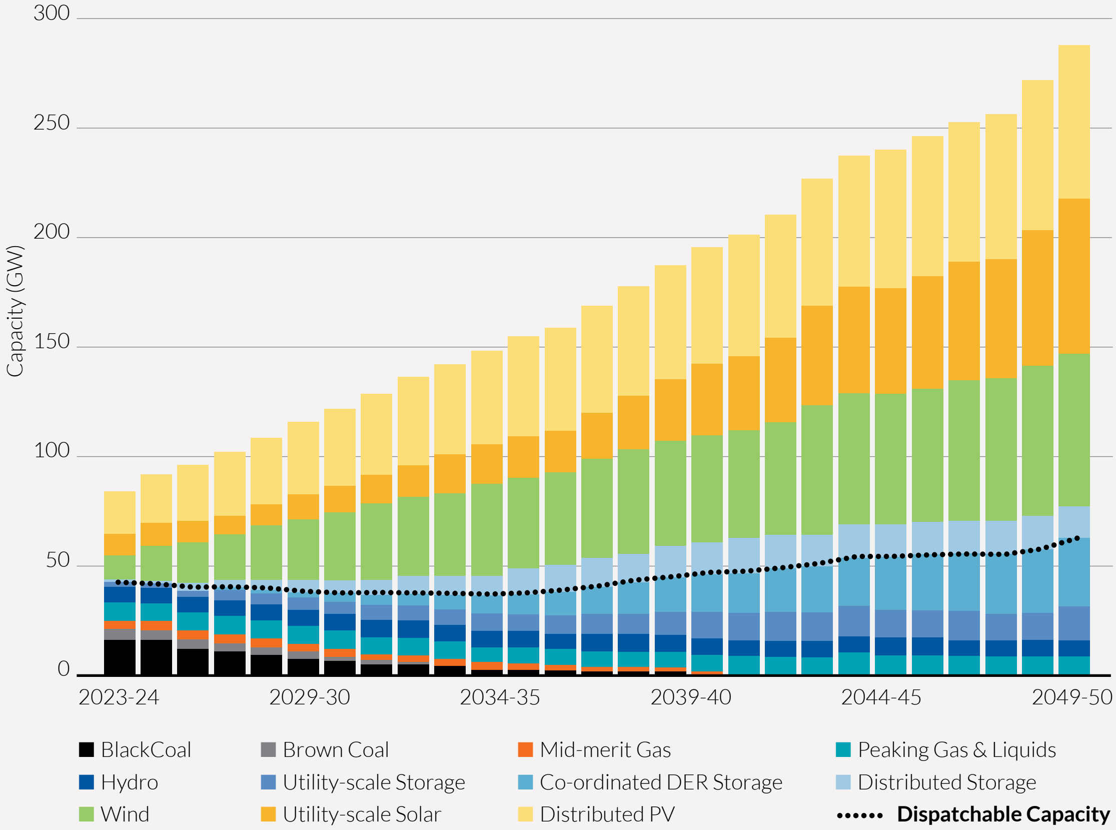
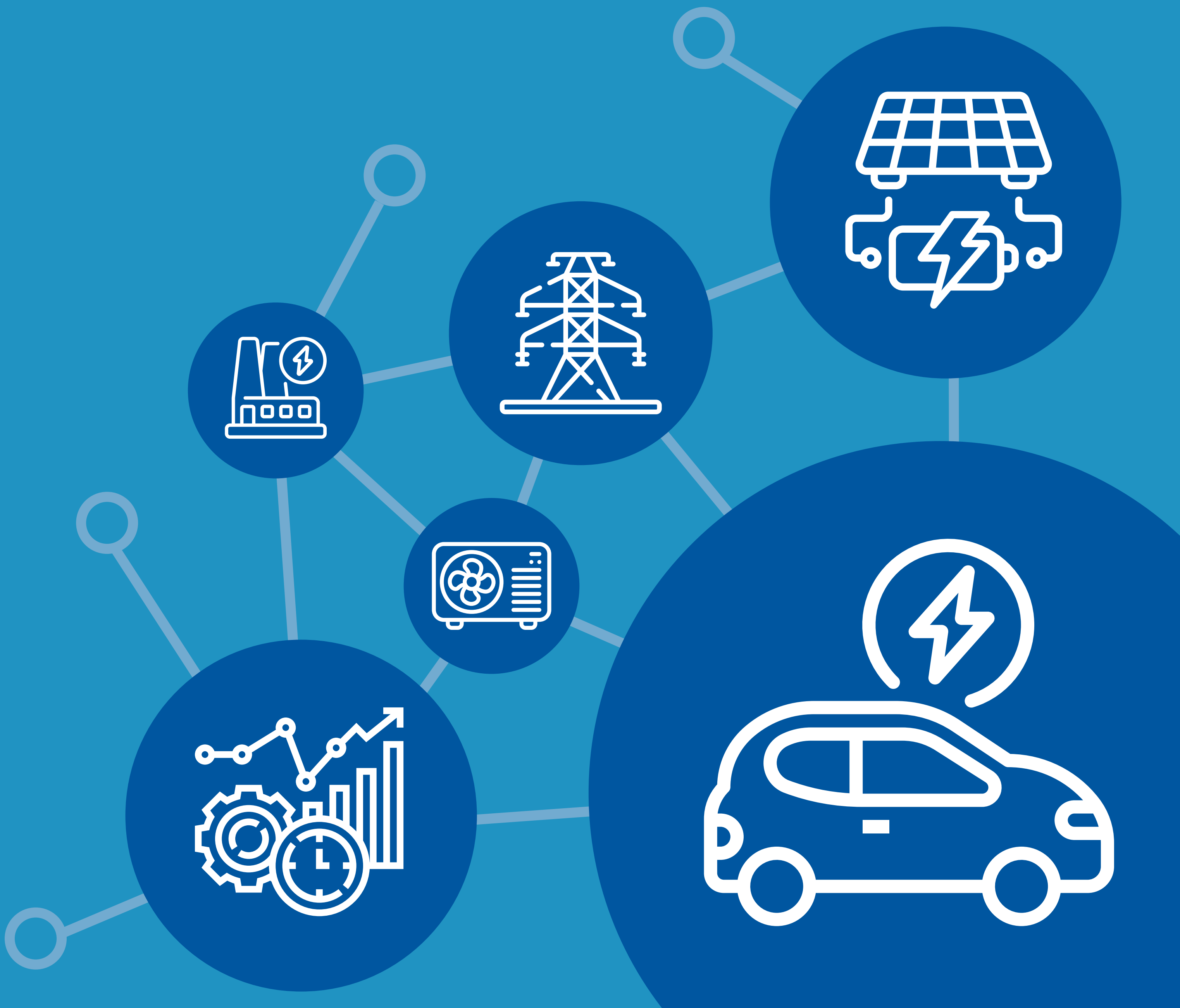



**Figure 4.6** Forecast NEM capacity to 2050, ISP Step Change scenario




Source: AEMO 2022 *Integrated System Plan – June 2022*, AEMO, Melbourne p.23

# 05 Efficient electrification and zero-emission fuels



## Summary

This chapter examines the likely pathways for reducing emissions from gas, petrol and diesel, and the implications for energy management. Efficient use of both fossil fuels and zero-emission fuels will have important functions, and electrifying buildings, transport and businesses *efficiently* will be vital to support rapid and affordable decarbonisation.

## 5.1 Reducing emissions from gas, petrol and diesel

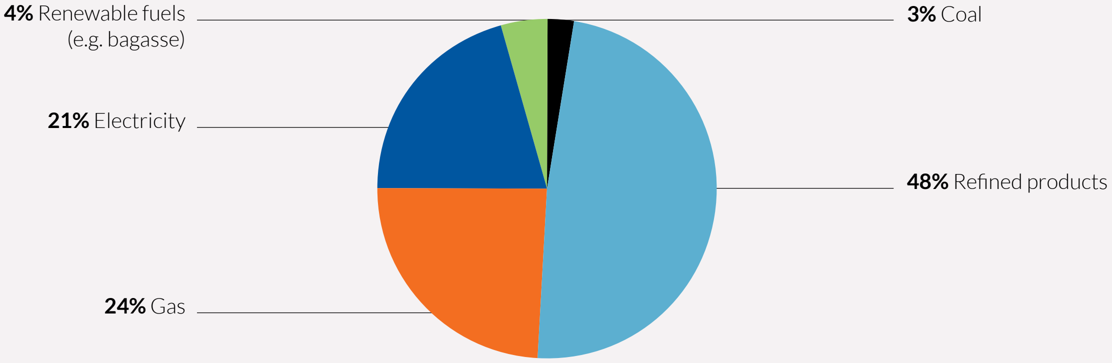
As mentioned in chapter 2, fossil gas,[63] petrol and diesel are used for energy in a wide range of services, predominantly:

- Cars and trucks with internal combustion engines (ICEV);
- Industrial processes such as manufacturing bricks; and
- Residential water heating and space heating, particularly in Victoria.

Households and businesses directly consume more gas and petroleum products than electricity. In 2020-21, gas and petroleum products accounted for 72 per cent of the energy that Australian homes and businesses used directly, with electricity accounting for just 21 per cent. Gas and liquid fuels are partly consumed in large volumes as they are generally converted into 'services' far less efficiently than electricity (Figure 5.1).

The domestic consumption of gas and liquid fuels account for around 40 per cent of Australia's emissions. To reach net zero emissions, Australia will need to almost completely eliminate the use of fossil gas, petrol and diesel.

### Figure 5.1 Australian total final energy consumption by fuel 2020-21

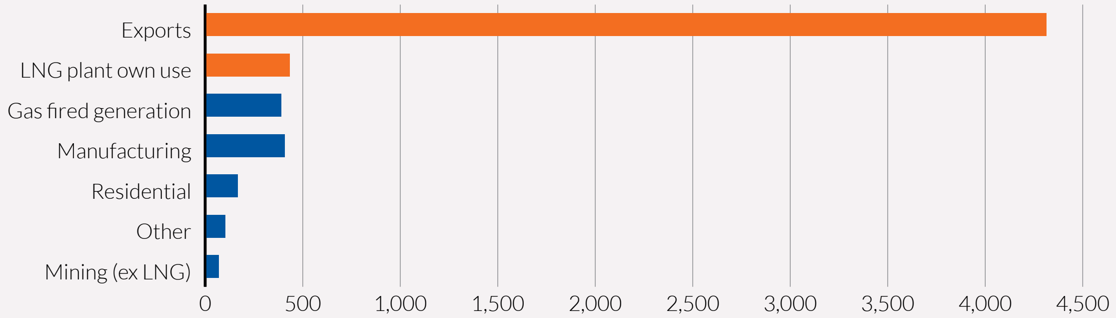



Notes: This chart excludes the fuels that are consumed to create electricity. 'Renewables' in this chart refers to the direct combustion of bagasse and other biofuels, and renewable generation is included under electricity.

Source: Department of Climate Change, Energy, the Environment and Water 2022, *Australian Energy Update 2022*, Commonwealth Government, Canberra.

63 Fossil gas is sometimes called 'natural gas'. In this report, gaseous fuels sourced from fossil fuel deposits are called 'fossil gas' to distinguish them from gaseous fuels derived from biological sources.

**Figure 5.2** Gas use in Australia, petajoules in 2020-21




Source: Department of Climate Change, Energy, the Environment and Water 2022, *Australian Energy Update 2022*, Commonwealth Government, Canberra.

This chapter focuses on the domestic consumption of gas, petrol and diesel, but it's worth noting that 73 per cent of the gas produced in Australia is exported, and a further 7 per cent is used to produce Liquified Natural Gas (LNG) for export. Australia will not be able to address its domestic greenhouse gas emissions without dealing with the fugitive emissions and gas consumption associated with gas extraction and export (Figure 5.2). For domestic energy users, there are five main routes to reducing emissions from gas, petrol and diesel:

- **Offsetting:** Using offsets to 'net out' emissions from gas, petrol and diesel
- **Fuel efficiency:** More efficient use of gas, petrol and diesel
- **Alternative fuels:** Substitution of gas and refined products with zero-emission fuels such as green hydrogen and biodiesel
- **Electrification:** Substitution of gas and refined products with electricity
- **Alternative services:** Substitution of one service (e.g. travel by petrol car) with an alternative service (e.g. walking, cycling, public transport)

The following sections examine the viability and likelihood of these five routes in different sectors. Of particular focus is viable emission reduction strategies in the next decade, which will be critical to reduce cumulative emissions and meet our interim emission reduction targets.

## 5.2 Offsets

Projects that reduce greenhouse gas emissions, such as investments in renewable energy, energy efficiency and reforestation, can be used to 'offset' emissions from other processes. Allowing companies to buy offsets to net off their emissions can help drive decarbonisation across the whole economy, but offsetting emissions from direct use of fossil-fuels is not a long-term strategy. It must be gradually wound down for two key reasons.

First, from a societal perspective, the volume of genuine negative emission opportunities (permanently removing carbon dioxide from the atmosphere, as opposed to avoiding creating emissions) is limited, and there are significant uncertainties about the volume and cost of the negative emission opportunities available. We should ideally reserve negative emission projects to deal with emissions that are currently unavoidable, such as those associated with some chemical processes.

Emissions from most fossil fuel use can be virtually eliminated relatively cost-effectively, reinforcing the value of a judicious approach to using offsets to net off fossil fuel use.

Second, for most energy users it will be far cheaper in the long-term to use alternatives to fossil fuels than pay for both fossil fuels and offsets. High quality negative emission offsets will likely become more expensive over coming decades, and in many sectors there are already cheaper alternatives to fossil fuels.

## 5.3 More efficient use of gas and refined products

Equipment that consumes fossil fuels, such as cars and boilers, vary significantly in their efficiency. A 6-star gas water heater can consume 39 per cent less gas than a 3-star model.[64] However, this equipment still uses fossil fuels, and ultimately, fossil fuel use must be eliminated to reach net zero. If a company invests in an efficient fossil gas boiler with a 30-year lifespan today, it will likely need to retire that boiler well before it reaches the end of its productive life.

Where mature zero-emission compatible substitutes are available – such as heat pump hot water systems – they will often be the more economic option to replace fossil fuelled equipment, even if existing equipment is still functional and the replacement has a higher upfront cost. Some governments have already signalled that all new buildings should be all-electric, partly because it will avoid owners from having to invest twice in energy-using equipment if they choose to electrify the building later.

Where mature zero-emission compatible substitutes are not currently affordable (as in some parts of industry, particularly those involving high temperature process heat), energy users will need to carefully consider whether to invest in more efficient equipment today, or hold off until technology substitutes become available. This will be a complex decision that companies should make in collaboration with energy management advisors, and governments have an important role in supporting businesses to adopt more innovative technology.

## 5.4 Biofuels

Biofuels refer to a wide range of carbohydrates that are sourced from recently-living biological materials (referred to as 'feedstock') rather than fossil fuel deposits. Biofuels include biodiesel, biogas and biomethane, but also solid fuels such as wood and bagasse (sugar-cane waste).

Where biofuels are created from locally-sourced waste products, they can be relatively cheap and have a small emissions footprint. For example, some sawmills burn wood waste to create heat and electricity and some piggeries convert pig waste into biogas. Where biofuel isn't produced from local waste feedstocks, its cost is generally much higher because of the cost of transporting the feedstock and/or producing feedstock on land that could otherwise be used for food, carbon sinks and biodiversity. As well as being more expensive than fossil fuel equivalents, biogas, biomethane and biodiesel not produced from local waste feedstocks are currently available in limited volumes.[65] Infrastructure Victoria's generous estimate is that:

'Victoria's total biogas and biomethane supply could reach around 40 PJ a year by 2050 – approximately one quarter of current natural gas use.'[66]

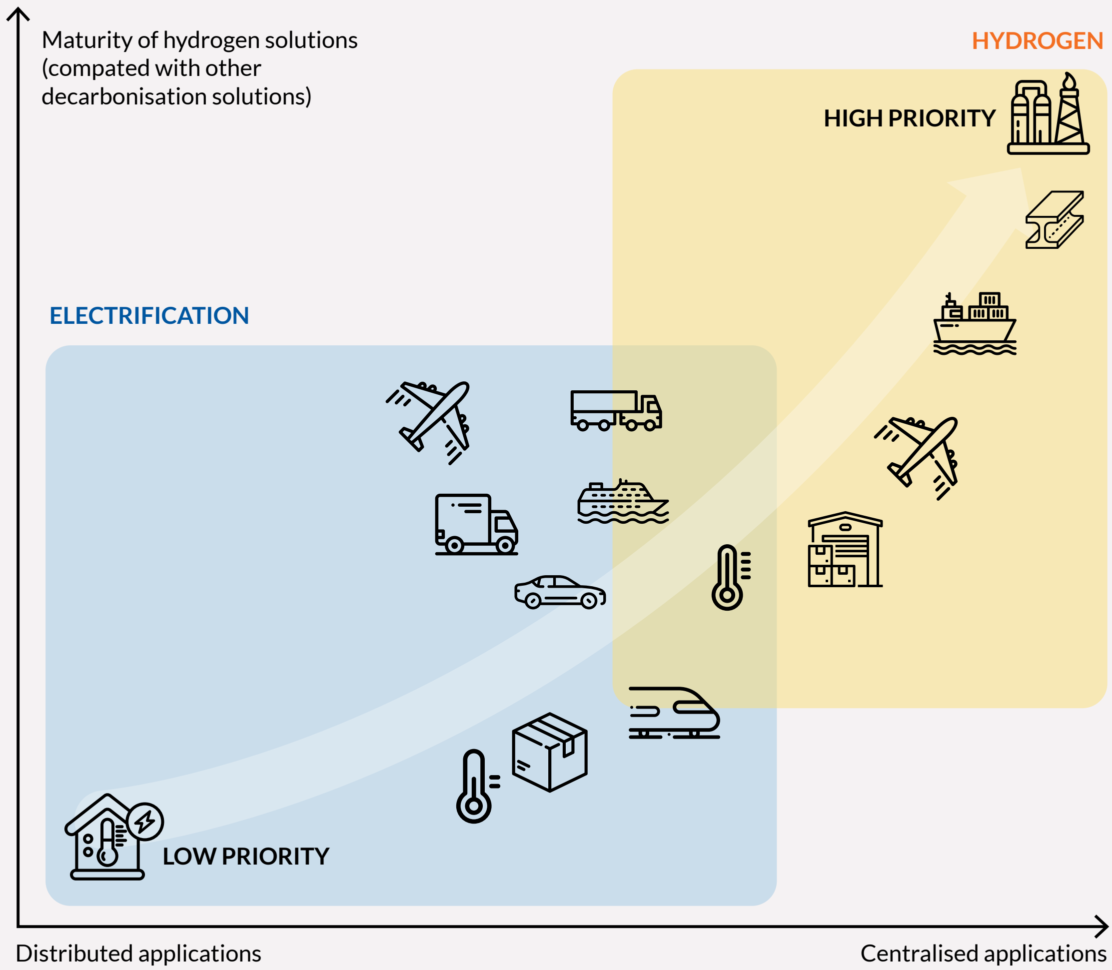
Based on current and prospective technologies, we believe it is highly unlikely that biofuels will be available at the price and volume that will become an economic wholesale replacement for natural gas in residential and commercial buildings in the next decade. However, biofuels will likely have valuable functions on particular sites and in localised industrial hubs with ready access to feedstock, or where alternatives are expensive or unavailable, such as aviation and long-distance freight.

64 Personal communications from Ian McNicol.

65 International Energy Agency 2020 *Outlook for biogas and biomethane*, IEA Paris.

66 Infrastructure Victoria 2022 *Towards 2050 – gas infrastructure in a zero emissions economy*, Infrastructure Victoria, Melbourne, p20 projects that Victorian electricity demand could increase from 200 PJ in 2020 to between 650 PJ and 810 PJ in 2050, p22.

**Figure 5.3** Relative advantage of hydrogen versus electrification for different applications




Source: International Renewable Energy Agency (IRENA), *The Geopolitics of the Energy Transformation: The Hydrogen Factor*, January 2022

## 5.5 Hydrogen

The vast bulk of hydrogen currently produced around the world is made by converting fossil gas into carbon dioxide and hydrogen, an emissions intensive product known as 'grey hydrogen.' Hydrogen can also be produced using an electrolyser powered by renewable energy, a zero emissions product known as 'green hydrogen'.

Green hydrogen is more of a form of energy storage, like a battery, than a source of energy. If green hydrogen can be economically produced by using excess renewable generation in the middle of the day, it could also potentially act as variable demand that helps to balance our electricity system.

Green hydrogen production is still in its infancy, with high production costs and low production volumes. Investments in research, development and commercialisation by organisations like the Australian Renewable Energy Agency will almost certainly increase production volumes and lower production costs, but we do not anticipate that substantial volumes of low-cost green hydrogen will be available before 2030.

Green hydrogen has a huge future market as a potential replacement for grey hydrogen, which is already used extensively in the production of ammonia, methanol and steel. Green hydrogen and its derivatives, including ammonia and synthetic kerosene, may also have significant markets for uses such as high-temperature industrial processes, larger vehicles and other specific end uses (Figure 5.3 ).

However, in the near-term, hydrogen does not appear to be competitive for widespread use in either cars or buildings. 'Fuel cell electric vehicles' that use hydrogen are currently more expensive to purchase and run than battery electric vehicles, and need access to specialist refuelling infrastructure.[67] As a result, the sales of fuel cell vehicles are substantially lower than battery vehicles in Australia and globally – the IEA estimates that fuel cell vehicles accounted for just 0.3 per cent of EVs on the road in 2020.[68] Based on current trajectories, battery vehicles appear likely to become the dominant technology for light passenger vehicles, with fuel cell vehicles restricted to more specific uses.

In buildings, electric heat pumps are more mature, more efficient and cheaper than hydrogen burners for space heating and water heating. Electric heat pumps are already widely used and can provide both heating and cooling. In contrast, pure hydrogen heaters can only provide heating and are currently only being used in a modest number of test-sites. There is also significant uncertainty about the cost and viability of modifying both appliances and our existing gas networks to transport hydrogen without extensive leakage.

Heat pumps have an apparent efficiency of 250 to 660 per cent efficient at using electricity to provide heat.[69] Green hydrogen boilers are substantially less than 70 per cent efficient at converting electricity into heating, taking into account the efficiency of converting electricity into hydrogen, pumping the hydrogen and turning hydrogen into heat.[70]

In other words, there is a likely need of at least five times as much electricity to power hydrogen heaters as there is to power heat pumps.[71] Taking into account the capital costs, maintenance costs and running costs, one assessment from Europe has suggested that using hydrogen for space heating would be double the cost of electrification. [72]

**In summary, while green hydrogen and its derivatives are likely to play a crucial role in certain sectors, such as manufacturing and heavy transport, the best available evidence suggests that hydrogen is unlikely to be competitive in the near term with electrification for the widespread replacement of gas, petrol and diesel in either buildings or light transport.**

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67 Morley, D. 2003 *How economical are hydrogen fuel cell vehicles?*, Cars Guide. Accessed on 24 February 2023 from https://www.carsguide.com.au/ev/advice/how-economical-are-hydrogen-fuel-cell-cars-88672

68 IEA 2021 *Hydrogen – tracking report September 2021*, IEA Paris. Accessed online on 4 August from: https://www.iea.org/reports/hydrogen

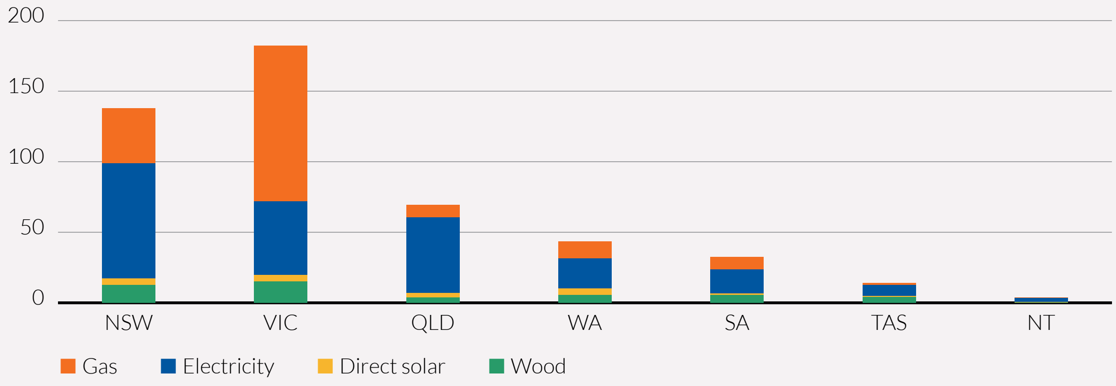
69 E3 Program *2021 Product profile – residential space heaters in Australia and New Zealand*, Australian Government Department of Industry, Science, Energy and Resources and the New South Wales Department of Planning, Industry and Environment.

70 Cebon, D. 2020 "Hydrogen for heating". Centre for Sustainable Road Freight. Accessed on 18 March 2023 at https://www.csrf.ac.uk/blog/hydrogen-for-heating/

71 Infrastructure Victoria 2022 *Towards 2050: Gas infrastructure in a net zero emissions economy*, Infrastructure Victoria, Melbourne.

72 Baldino, C., O'Malley, J., Searle, S. and Christensen A. 2021 *Hydrogen for heating? Decarbonization options for households in the European Union in 2050*, International Council on Clean Transport.

**Figure 5.4** Residential energy consumption by fuel 2020-21




Source: Australian Energy Statistics 2022 Table F and Australian Sustainable Built Environment Council 2022 *Unlocking the pathway, why electrification is the key to net zero buildings*, ASBEC, Sydney.

## 5.6 Electrification by sector

Electricity already plays a substantial role in Australia's economy, and the potential for electrification of gas, diesel and petrol use is largely limited by the availability and cost of electrical equipment that can substitute for equipment that uses fossil-fuels. Electrification can rapidly decarbonise buildings and transport, and there are growing opportunities for electrification in industry.

### Electrifying residential and commercial buildings

In most states in Australia, electricity is already the dominant fuel in homes, with gas used largely for cooking and, in a smaller proportion of homes, space heating and hot water.[73] However, in Victoria and the ACT, gas is the dominant fuel in homes. In Victoria it is used for space heating in over 60 per cent of homes, and water heating in over 70 per cent of homes (Figure 5.4).[74]

There are mature electrical technologies that can substitute for gas in space heating, water heating and stoves. Heat pumps for space heating and cooling, and heat pumps for water heating, can operate at more than four times the apparent efficiency of gas-fired equivalents. As a result, heat pumps are typically a lot cheaper to run than gas-fired heaters, and produce substantially less emissions. Even if heat pumps use electricity solely from gas fired generation, they would still produce less than half the emissions of a gas water heater.[75]

The expert group Renew estimates that households would save $9,000 to $16,000 over 10 years if they build new homes as all-electric (with solar) instead of having both electricity and gas.[76] For existing homes, when gas-fired appliances reach the end of their life, it will generally make financial sense to replace them with electric appliances, although there will be some homes where site-specific issues and wiring upgrades make it more challenging and/or expensive.[77]

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73 Energy Consult 2015 *Residential Energy Baseline Study – A report for the Australian Department of Industry and Science*, Energy Consult, Jindivik.

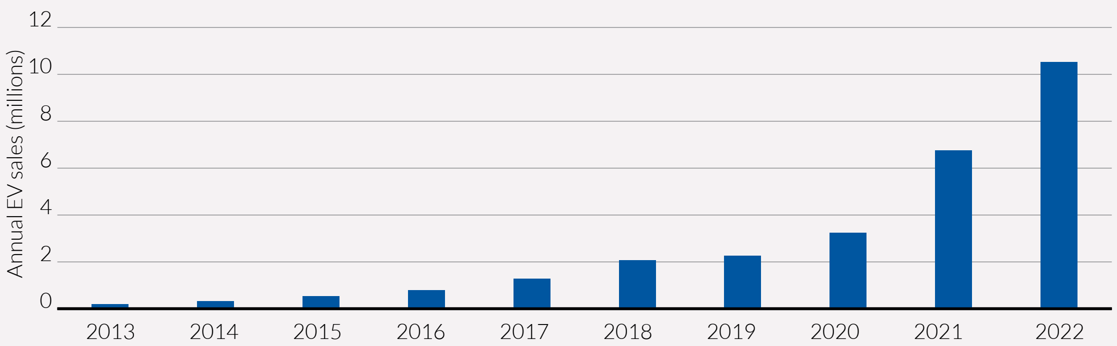
74 Ryan, P. and Pears, A. 2019 Unravelling home energy use across Australia, *https://renew.org.au/renew-magazine/efficient-homes/unravelling-home-energy-use-across-australia/*

75 Based on the average gas-fired generator efficiency in Australia and allowing for network loses and a heat pump with a COP of 4, versus a gas water heater with an efficiency of 90 per cent. E3 Program *2021 Product profile – residential space heaters in Australia and New Zealand*, Australian Government Department of Industry, Science, Energy and Resources and the New South Wales Department of Planning, Industry and Environment.

76 Alternative Technology Association (Renew) 2018 *Household fuel choice in the National Electricity Market*, Alternative Technology Association, Melbourne.

77 Alternative Technology Association (Renew) 2014 *Are we still cooking with gas? Report for the Consumer Advocacy Panel*, Alternative Technology Association, Melbourne.

**Figure 5.5** Global annual sales of EVs (BEV and plug-in hybrid)




Source: EV volumes 2023 *The global electric vehicle sales database*, EV-volumes.com, Accessed online 18 February 2023 from: https://www.ev-volumes.com/

Electrifying homes at the pace needed to meet Australia's greenhouse gas targets presents a challenge. To eliminate gas use by 2050 in Victoria alone, around 200 homes would need to be electrified every single day over the next 27 years. To achieve this, we will need a large skilled workforce focused on retrofitting homes, along with community buy-in and significant investment to support lower-income households to undertake retrofits.

For new commercial buildings, it is relatively straightforward to build all electric, although demonstration projects will be critical to spread this practice. For many existing commercial buildings, it will be economic to replace existing gas equipment with electrical equipment although, again, demonstration projects will be critical. Some existing commercial buildings with centralised plant-rooms will be more challenging to electrify, and will require active partnerships between government and industry to run pilot projects and share learnings.[78]

## Electrifying transport and alternative services

A range of EV models are already available, and are generally more than three times as efficient as ICEV in converting stored energy to movement.[79] As a consequence, even if EVs use electricity that was entirely generated with fossil fuels, their emissions would be between 5 and 29 per cent lower than ICEVs.[80]

Almost all major auto manufacturers are either already producing EVs, or are planning to. Annual global sales of EVs (battery electric vehicles [BEV] and plug-in hybrid) have increased fifty-fold over the past 10 years (Figure 5.5) and in 2022 EVs accounted for 13 per cent of global light vehicle sales.[81] With a range of countries committing to effectively banning the sale of new light ICEV by or before 2040, including Canada, the European Union and the UK, EVs are likely to dominate global vehicle sales by 2030. EV uptake in Australia is still lagging other developed countries, but uptake is accelerating.[82]

78 Energy Efficiency Council and Australian Alliance for Energy Productivity 2023 *Harnessing heat pumps for net zero*, Energy Efficiency Council, Melbourne.

79 US Department of Energy 2022 *Fuel Economy – EV tech*, US Department of Energy, Washington. Accessed online on 24 August from https://www.fueleconomy.gov/feg/evtech.shtml

80 Smit, R. 2021 "A probabilistic life cycle assessment comparing greenhouse gas emissions from electric and fossil fuelled vehicles in Australia," *Air Quality and Climate Change Journal*, 55(1) 36-37

81 EV volumes 2023 *The global electric vehicle sales database*, EV-volumes.com, Accessed online 18 February 2023 from: https://www.ev-volumes.com/.

82 Federal Chamber of Automotive Industries 2023 *New Car Sales data for 2022*. Accessed online on 18 February from https://www.fcai.com.au/news/index/view/news/787.

Petrol and diesel use in transport could also be reduced by upgrading our cities to support walking, cycling, public transport and small EVs (e.g. electric scooters). Australian cities currently prioritise car-based transport, which results in a much higher proportion of trips being made by car than in many other countries. Our car-centric cities have negative impacts on emissions and household budgets, but also negative impacts on: exercise and health; urban function and amenity; and mobility for the roughly 30 per cent of Australians who don't have drivers licences.[83]

For freight, electric light trucks are well suited to urban areas, as they are quieter, less polluting and substantially more efficient than ICEV. EVs may take longer to dominate heavy trucking, and given travel distances in Australia, hydrogen and biodiesel could play a significant role in heavy freight. It will also be important to introduce complementary measures to reduce emissions from freight, such as better logistics planning and consolidating freight onto fewer vehicles to reduce energy per tonne of freight transported.

## Electrifying mining

The mining sector (including fossil-fuel extraction and processes) uses a large amount of diesel and gas to generate electricity, run vehicles and power machinery.[84] [85] A significant proportion of the mining haul fleet is already electric drive, with diesel used to generate power. Electrification of some functions could happen quite rapidly – for example electrifying underground equipment will deliver not just energy and carbon savings, but also improve air quality.

However, full electrification of the mining sector is not straightforward. There are cost and operational constraints associated with substituting batteries for diesel in functions such as mining haul.

A transition to electric mines will be impeded by the time it takes to develop some types of equipment; the remaining lifespan of existing fossil-fuel powered equipment; and the need to balance technical advances and upgrades with demanding production schedules. In addition to electrifying end-use equipment, the mining sector will need to address storage costs, and expand and decarbonise its electricity generation. This suggests a significant role for governments in supporting research, development and commercialisation to enable the electrification of mining.

## Electrifying manufacturing

Australia's manufacturing sector uses twice as much gas as the residential sector. In 2019-20, gas accounted for 42 per cent of final energy use in manufacturing.[86] A broad range of manufacturers use gas, including non-ferrous metals, chemicals producers and food, beverage and textiles (Figure 5.6 ).

Around 16 per cent of the gas consumed in manufacturing is used as feedstock and other non-energy uses, for products such as propylene.[87] The vast majority is used for energy. The ability of electricity to substitute for gas in heating depends on the temperature and the process. Electricity can readily substitute for process heat under 100 degrees, and a proportion of process heat up to 400 degrees, but not currently for higher temperatures.[88]

83 This Bureau of Infrastructure, Transport and Regional Economics (2017), *Drivers Licences in Australia* BITRE, Canberra.

84 Department of Climate Change, Energy, the Environment and Water 2022, *Australian Energy Statistics – Table H*, Commonwealth Government, Canberra.

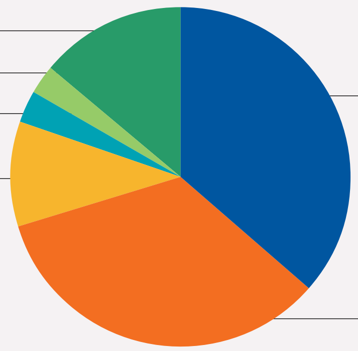
85 Sunshift 2017 *Renewable energy in the Australia mining sector – white paper*. Sunshift, Sydney.

86 Department of Climate Change, Energy, the Environment and Water 2022, *Australian Energy Update 2022*, Commonwealth Government, Canberra.

87 Department of Climate Change, Energy, the Environment and Water 2022, *Australian Energy Update 2022*, Commonwealth Government, Canberra.

88 Maddedu, S. et al. 2020 "The $CO_2$ reduction potential for the European industry via direct electrification of heat supply (power-to-heat)" *Environmental Research* Letters 15(12).

**Figure 5.6** Industry use of gas in 2020-21




Department of Climate Change, Energy, the Environment and Water 2022, *Australian Energy Statistics* – Table H, Commonwealth Government, Canberra.

However, the manufacturing sector is risk-averse to adopting novel technologies that might interfere with production, and there has been relatively little large-scale demonstration of these technologies. Government support for demonstration of mature electrification technologies in manufacturing will be critical to their uptake, as well as funding for research, development and demonstration of prospective technologies for higher-temperature processes.

In summary, a significant proportion of gas use in manufacturing could be substituted with electricity today, but further research and development will be required to decarbonise the sector, and biofuels and hydrogen could play significant roles in eliminating fossil gas in industry.

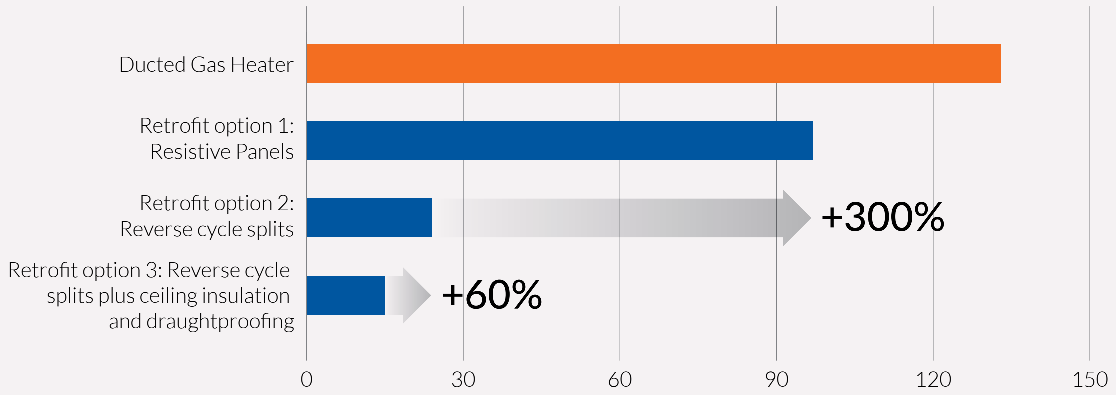
## 5.7 Energy management

This chapter looked at the viability of key options for reducing emissions from gas, petrol and diesel over the coming decade, and eventually eliminating emissions from direct use of fossil fuel. The evidence suggests that electrification is the most likely and economic route for replacing fossil fuel use in buildings and light vehicles, and the transition could happen quickly. Electrification is also likely to be the primary pathway for decarbonisation for manufacturers and food processors that rely on low temperature process heat. For other parts of industry, mining and heavy transport, a combination of electrification and zero-emission fuels may be required to eliminate the use of fossil fuels.

**The first conclusion for energy management is that while efficient use of gas, petrol and diesel can help reduce emissions from those fuels, it cannot eliminate them.**

Furthermore, in most sectors, alternatives to these fossil-fuels are either available or emerging. Energy users need to carefully weigh the pros and cons of investing in long-lived equipment that uses fossil-fuels more efficiently, but there are two broad categories of sensible investments energy users should consider to improve the efficient use of gas and refined products:

**Figure 5.7** Energy required to heat an average Melbourne house on a winter's day (kWh)




Source: Modelling by Light House Architecture and Science, based on a real 160m$^2$ house built in the 1970s. The home had poor thermal efficiency, and a small investment in ceiling insulation and draughtproofing would more than double its NatHERS rating from 1.5 stars to 3.2 stars.

- **Efficiency improvements that are 'paid-off' rapidly:** Some efficiency improvements have a high enough cost-benefit ratio (taking into account both costs and emission savings) that they are worth doing even if they are to be replaced in a few years. For example, adding controls to a gas-fired boiler could reduce energy bills and emissions at relatively low cost.
- **Investments compatible with both fossil-fuels and zero-emission fuels:** Investments in components that *complement* fuel-consuming devices continue to deliver value even after the fuel-consuming device is replaced. For example, insulating a building will reduce energy bills and emissions, even after its gas-fired heater is replaced. There are many types of energy efficiency like this, such as improved controls and insulating pipes on industrial sites. This argument does not extend to equipment that directly consumes fossil fuels (e.g. boilers), as there are significant uncertainties about the cost and availability of biofuels and hydrogen, and significant uncertainties about the cost of retrofitting appliances to run on hydrogen.

The second conclusion for energy management is that efficient use of biofuels and hydrogen will be important to their affordability, given their high cost.

The most significant finding is that electrification is already not only possible, but economic in many sectors.

Given that gas, petrol and diesel currently account for 74 per cent of energy directly used by consumers, substantial electrification would significantly increase overall electricity consumption.

Even taking into account the much greater efficiency of heat pumps and EVs, electrification could result in Australian electricity demand more than doubling. In Victoria, where gas use is higher, analysis has suggested a combination of electrification and other factors could see annual electricity demand more than triple between 2020 and 2050.[89]

As the following chapters explore, minimising the growth in electricity demand at key times will be important to improve the affordability of electricity and buy us time to better plan the expansion and decarbonisation of electricity supply. In particular, recent research from the United States suggests the efficiency with which buildings are electrified will have a major impact on the amount of generation and storage that needs to be built in that country.[90]

There are many simple options to ensure electrification is efficient, including:

- Installing high-efficiency heat pumps for hot water and space conditioning;
- Insulating and draught proofing buildings, which will also enable some pre-heating and pre-cooling;
- Buying more efficient electric vehicles; and
- Ensuring the transition to heat pumps for low temperature process heat is accompanied by broader process optimisation and energy productivity enhancements (Figure 5.7).

Figure 5.7 illustrates three options to electrify the heating system of an older home in Melbourne. The difference in energy use between the three is stark – on an average day in July, Retrofit option 1 would use more than six times as much electricity as Retrofit option 3. In addition, the costs of Retrofit options 2 and 3 are very similar – insulating and draughtproofing a 160m$^2$ home could reduce the amount that needs to be invested in reverse cycle heaters by 50 per cent – as a result, the total estimated cost of Option 3 is $12,800, only slightly higher than the total cost of Option 2, at $11,200, as per modelling provided by Light House Architecture and Science.

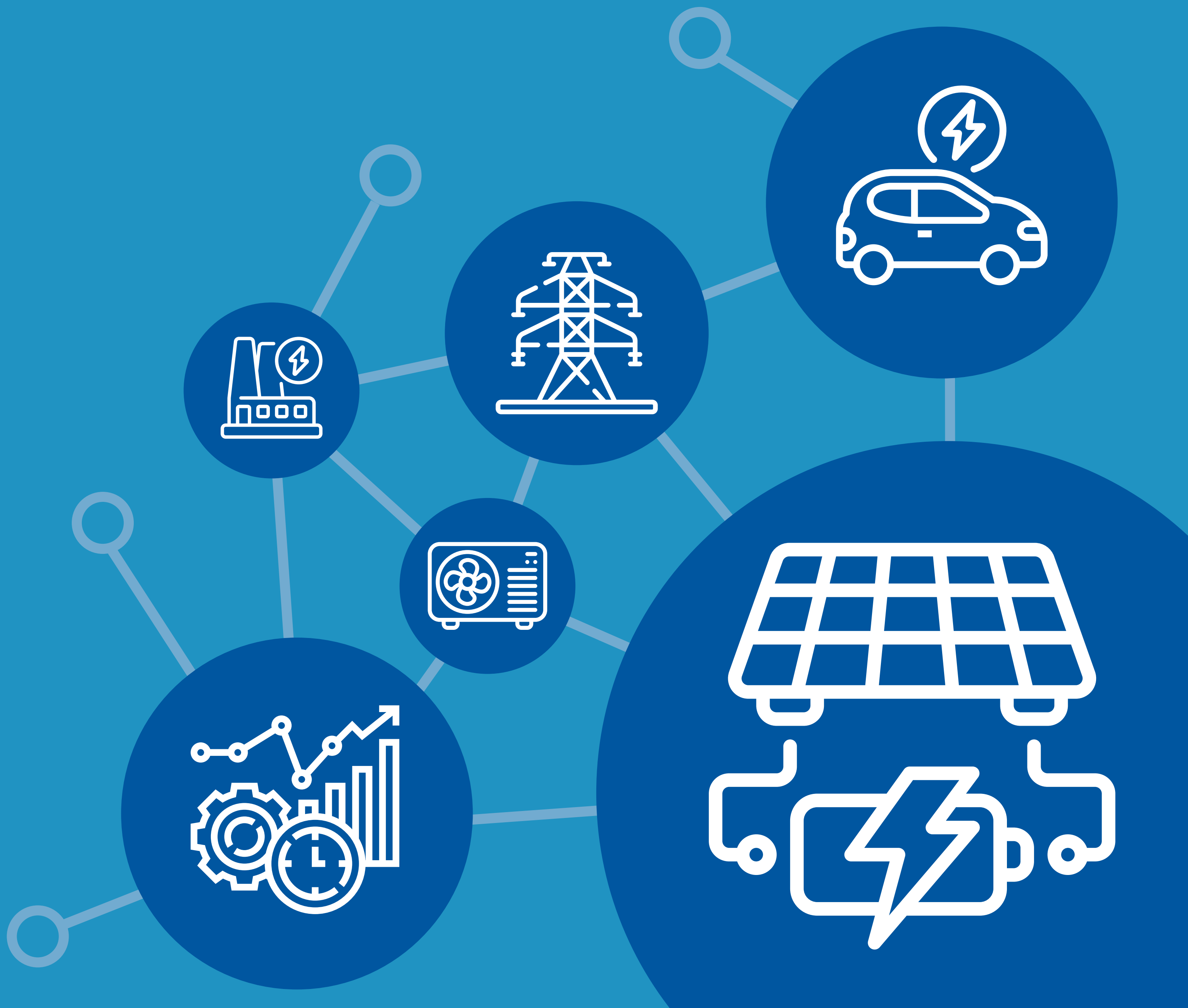
In other words, combining appliance electrification and building upgrades will deliver homes that are cheaper to run, use less energy and are far more comfortable.

Electrification will also have a much lighter impact on the grid if due consideration is given *when* appliances and vehicles consume energy. Hot water can very easily run during the middle of the day and EVs can often be charged in ways that minimise their impact. Given that we have a very small window to prepare for the impacts of millions of EV and electric homes connecting to the grid, urgent planning is required to get this right.

89 Infrastructure Victoria 2022 *Towards 2050 – gas infrastructure in a zero emissions economy,* Infrastructure Victoria, Melbourne, p20.

90 Buonocore, J. Salimifard, P, Magavi, Z. and Allen, J. 2022 "Inefficient building electrification will require massive buildout of renewable energy and seasonal energy storage", *Scientific Reports* 12, 11931.

# 06 Reliable and affordable electricity capacity



## Summary

This chapter examines how to deliver a reliable and affordable renewable energy system. The most cost-effective way to ensure there is always sufficient supply to meet demand is to invest in a mix of wind and solar, storage, dispatchable generation and, critically, energy management.

## 6.1 A reliable, affordable, zero-emission grid

Our electricity system should aim to reach, or be close to, zero emissions well before 2040, but it also must be reliable and affordable. The Integrated System Plan (ISP) defines reliability as *"a sufficient overall portfolio of energy resources to continuously achieve the real-time balancing of supply and demand."*[91] This definition takes into account generation, storage and networks. Critically, this definition also makes clear that *changes in demand* can have a significant impact on reliability.

To ensure an affordable electricity system, investment in generation, storage and networks must be limited to that which is necessary to reliably deliver energy services. This chapter looks ahead to a period when Australia's electricity system is decarbonised, and for clarity often refers to the 2022 ISP 'Step Change' scenario explained in section 6.2, and considered most likely by experts.

This chapter focuses on investments in generation and storage including consumer investment, and assumes these costs will be passed on to consumers in some form. Chapter 7 looks at network costs and Chapter 8 considers coordinating and optimising investment.

## 6.2 Renewable generation

The ISP Step Change scenario for the future of the grid assumes that in 2050 the vast majority of Australia's generation capacity will be distributed solar, utility solar and wind.[92]

As noted in Chapter 4, wind and solar generation are currently the cheapest sources of electricity per MWh generated, and their costs are projected to fall even further to 2040.[93] When solar and wind are at peak production they produce very cheap electricity. The challenge is that variable renewables require support to properly integrate with the grid, and their output varies in only semi-predictable ways. Solar output varies on a predictable 24-hour cycle, and declines over winter months and when there is cloud cover. Wind generation tends to be more consistent across the year, but its output is more variable on any given day.

### An energy system dominated by solar and wind will have times when generation is lower than average – sometimes this will coincide with times when demand is higher than average, creating 'pinch-points'.

These include relatively short periods, like summer evenings, and longer periods of unfavourable weather. While the risks of long, uninterrupted 'renewable energy droughts' are often overstated, production in winter will generally be lower than in summer, and if there are multiple periods of low solar and wind output, cumulative generation over a whole season could be lower than demand (Figure 6.1).[94, 95]

Many experts expect Australia will build a significant amount of storage to address periods when supply is lower than demand. Storage is expensive, and minimising how much is spent on it will lower the overall energy system cost. This chapter looks at four options that help reduce the need for storage and system cost:

- Dispatchable generation;
- Diversity in renewable generation type and location;
- 'Oversizing' renewables; and
- Energy management.

91 AEMO 2022 *Integrated System Plan – June 2022*, AEMO, Melbourne p.23.

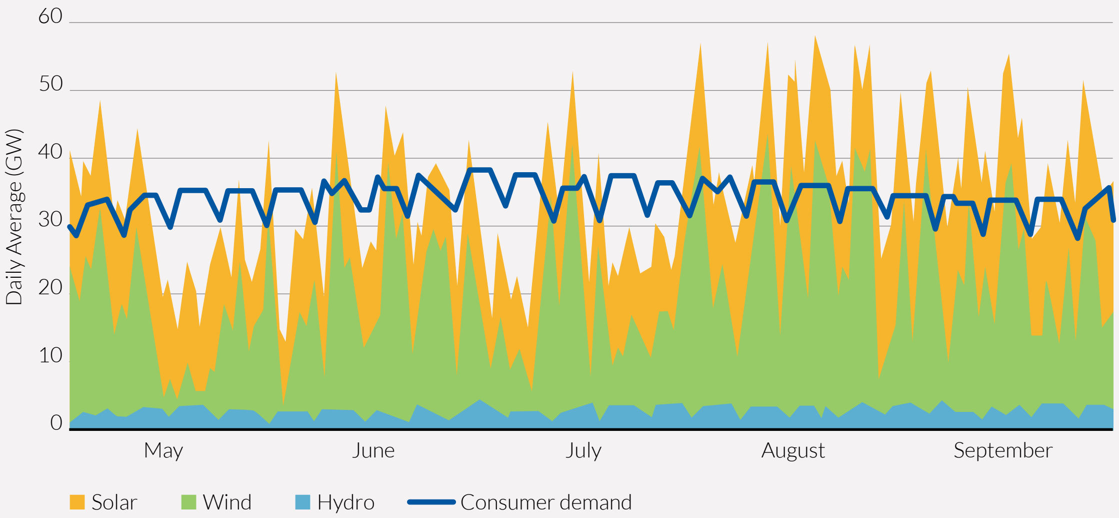
92 AEMO 20222 *Integrated System Plan – June 2022*, AEMO, Melbourne, p9 Figure 1.

93 Graham, P., Hayward, J., Foster J. and Havas, L. 2022, *GenCost 2021-22: Final report*, CSIRO, Canberra.

94 Gilmore, J, Nelson, T. and Nolan, T. 2022 *Quantifying the risk of renewable energy droughts in Australia's National Electricity Market using MERRA-2 weather data. Centre for Applied Energy Economics and Policy Research Working Paper Series 2022-03*, Griffith University, Brisbane.

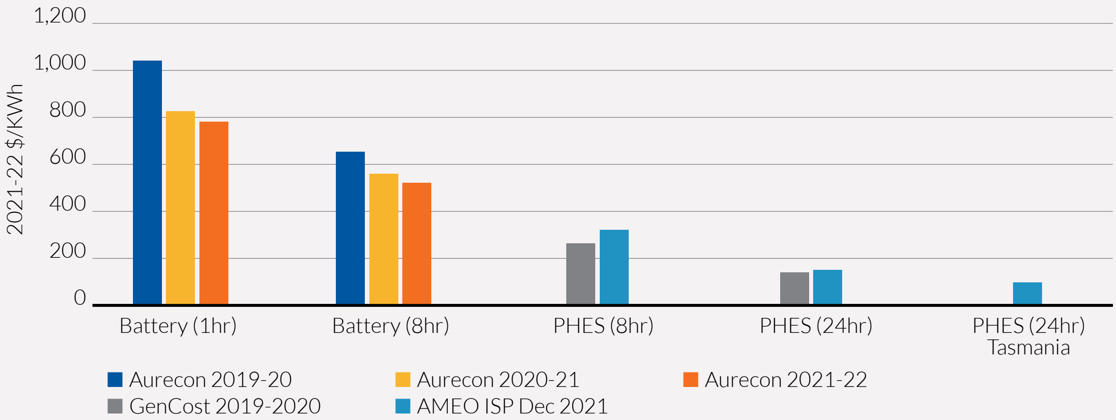
95 Boston, A. Bongers, G. and Bongers, N. 2022 "Characterisation and mitigation of renewable droughts in the Australian National Electricity Market", *Environmental Research Communications* 4 031001.

**Figure 6.1** Modelling indicating periods of generation shortfall in a 100 per cent renewable NEM




Derived from Boston, A. Bongers, G. and Bongers, N. 2022 "Characterisation and mitigation of renewable droughts in the Australian National Electricity Market", Environmental Research Communications 4 031001 Figure 1

**Figure 6.2** Capital costs of storage technologies in $/kWh (total cost basis) in 2021-22




Source: Graham, P., Hayward, J., Foster J. and Havas, L. 2022, GenCost 2021-22: Final report, CSIRO, Canberra.

To have a reliable and affordable grid, we will need to get the right balance of all these strategies. While this report focuses on the role of energy management, we must first understand the other resources.

## 6.3 Storage

Storage can deliver a range of valuable functions, including frequency control. This section focuses on the role of storage as capacity, ensuring demand is met when it is higher than generation. The ISP Step Change scenario suggests that 47 GW of distributed and utility storage needs to be built by 2050, including pumped hydro and batteries.

In the right locations, pumped hydro can provide storage at moderate prices. However, the build cost of pumped hydro can vary significantly between sites and the volume of *low-cost* pumped hydro that is available in Australia is uncertain. Like many large-scale civil engineering projects, the Snowy Hydro 2.0 scheme highlights that building pumped hydro is not necessarily straightforward or cheap. As pumped hydro is a relatively mature technology, CSIRO expects its costs per MW will decline by less than 6 per cent between 2020 and 2050 (Figure 6.2).[96]

In contrast to pumped hydro, batteries are currently extremely expensive, but their cost is declining rapidly. Large batteries currently cost over $500 per kWh for 2-hour storage, and small-scale batteries around $1,000 to $1,400 per kWh, including installation and GST. The build cost of lithium batteries fell around 97 per cent between 1991 and 2018, and could fall by a further 40 to 75 per cent by 2050.[97, 98]

However, consuming energy from stationary batteries is, and will remain, much more expensive than directly consuming energy at the time it is generated by wind and solar. Using batteries degrades them, which means both the long-duration and short-duration pinch points have a cost. Translated to a cost per cycle, a home battery would currently cost around 27 to 38 cents per kWh cycle. Even if the cost of batteries fell by 80 per cent, to 5.4 to 7.6 cents per kWh, this would still mean the 'wholesale' cost of using energy generated by solar or wind and stored could be more than double the cost of using renewable energy at the time it is generated.

EVs could potentially offer lower overall cost storage than stationary batteries, due to larger economies of scale and the distribution of the costs of an EV between home energy storage and transport.

EVs could be used to store excess energy from the grid and feed it back into the grid when homes and businesses need it, which is sometimes called 'vehicle-to-grid' (V2G). However, V2G isn't costless – charging and emptying vehicle batteries for grid purposes would reduce their lifespan, increasing the need to replace them.

With potentially millions of EVs connected to the grid by 2035, there could be a significant amount of V2G storage by this date.

The ISP suggests that in 2050, V2G and virtual power plants could provide around 31 GW of storage capacity, almost twice that delivered by utility-scale batteries and pumped hydro. There is considerable uncertainty about just how much storage will be provided by V2G, and this uncertainty relates as much to cultural as technical factors. To offer V2G services, vehicles need to be plugged in at the right time and in the right location, which might conflict with their primary purpose of moving people and goods around.

It is clear the future zero emissions electricity grid requires investment in electricity storage. But the less storage needed, particularly in the next decade when storage costs are likely to be higher, the more affordable energy will be.

96 Graham, P., Hayward, J., Foster J. and Havas, L. 2022, *GenCost 2021-22: Final report*, CSIRO, Canberra.

97 Zeigler, M. and Trancik J. 2021 "Re-examing rates of lithium-ion battery technology improvement and cost decline" *Energy and Environmental Sciences*, 2021, 14, 1635-1651.

98 Graham, P., Hayward, J., Foster J. and Havas, L. 2022, *GenCost 2021-22: Final report*, CSIRO, Canberra.

## 6.4 Dispatchable generation

Storage can be complemented by flexible 'dispatchable' generation that can run when wind and solar aren't generating enough power to meet demand. The most useful complements to variable renewables are flexible generators like hydro and thermal plants that burn liquid or gaseous fuels (e.g. fossil or renewable gas). Less flexible generators, like coal-fired and nuclear generators, are poorer complements to a high-renewables grid.

Hydro generation is an extremely useful energy resource. It is zero-emission, can rapidly increase or decrease its output, and includes storage. However, geographical and climatic factors mean there are very few opportunities to build new hydro generation in Australia, and the impacts of climate change are making rainfall to power hydro generation more variable and less predictable.[99] Accordingly, the ISP assumes only the current 7GW of hydro generation already on the NEM will be operating in 2050.

The ISP's Step Change scenario assumes gas peaking plants will provide around 10 GW of capacity in the NEM until 2050. As gas generators are expensive and emissions-intensive to run, their operation must be minimised. It would be possible to build peaking plants that run on renewable fuels, such as biogas or hydrogen, but these fuels are currently significantly more expensive than fossil gas and their availability is currently constrained.

Dispatchable generation will play an important role in the grid, but the volume of capacity it provides will be limited by its price, emissions and, in the case of hydro, opportunities. Accordingly, the ISP assumes that in 2050, dispatchable generation will provide less than a quarter of the capacity provided by storage. As with storage, keeping energy affordable will require minimising demand that necessitates the construction and operation of dispatchable generation.

## 6.5 Diversity in types and location of renewable generation

One of the most critical routes to having sufficient electricity when it is needed is a diverse mix of renewable energy. Having a mix of solar and wind generation on the grid means it is more likely some generation will be available at all times, reducing the need for storage and dispatchable generation (Figure 6.3).

The ideal mix of renewable generation technologies to deliver reliable power will vary geographically, based on patterns of energy demand and wind and solar resources. For example, Houssainy and Livingood, researchers at the US National Renewable Energy Laboratory (NREL), estimate the optimum mix of renewable generation varies across the United States of America, including:

- 100 per cent wind in the north of the US, as poor solar output in winter would be insufficient to meet high demand for heating; and
- 60 per cent solar and 40 per cent wind in the west of the US, where solar resources are better and winter heating demand more modest.[100]

Another way to diversify the output of renewable energy generation is to source it from a wider geographic area.

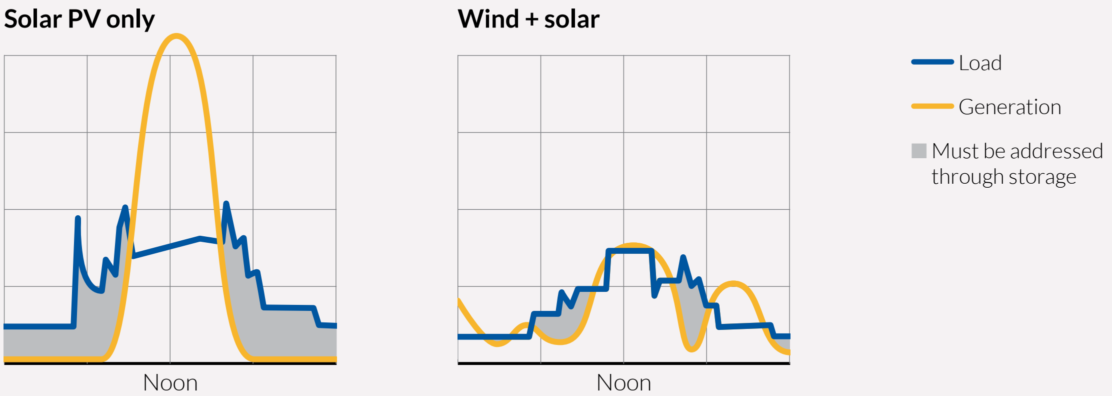
Wind farms in a similar location – such as within South Australia – are likely to have similar outputs. However, wind farms in South Australia have very different outputs to those located a greater distance away, such as Queensland. Investing in transmission to link regions within the NEM will increase the amount of renewable generation that is always available to consumers. Interconnection can also provide more diversity in load, as people in Queensland and South Australia are likely to have differing needs for heating based on their respective weather patterns.

While investment in some transmission will likely be essential, it is not a panacea. Significant inter-regional transmission projects require investments in the hundreds of millions to billions of dollars, so the merits of each transmission project should be thoroughly assessed before investment is made. There are also challenges building transmission in the timeframes suggested in the ISP, and limits to the ability of transmission to eliminate undersupply of energy. Finally, over-reliance on transmission for energy security can create risks. When a region is heavily dependent on a small number of co-located transmission lines for its energy security, damage to those lines through storms and bushfires can cause major problems.

99 Pendergrass, A.G., Knutti, R., Lehner, F. *et al.* 2017 "Precipitation variability increases in a warmer climate" *Scientific Reports* 7, 17966.

100 Houssainy, S. and Livingood, W. 2021 "Optimal strategies for a cost-effective and reliable 100% renewable grid", *Journal of Renewable and Sustainable Energy* 2021, 13.

**Figure 6.3** Diversifying generation to reduce storage costs




Source: Derived from Houssainy, S. and Livingood, W. 2021 "Optimal strategies for a cost-effective and reliable 100% renewable grid", Journal of Renewable Sustainable Energy 2021, 13, Figure 1

## 6.6 'Oversizing' renewables and shedding

Another strategy to ensure sufficient electricity is available during pinch points is to build renewable generation so annual generation (MWh) exceeds annual consumption – sometimes called 'oversizing'.[101] The advantage of 'oversizing' renewables is that more electricity is produced during pinch points, significantly reducing the risk of supply being lower than demand, and reducing the amount of storage that needs to be built (Figure 6.4).[102]

A grid with oversized renewables will often generate more electricity than required. Some of this excess can be stored, but it would be prohibitively expensive to build the networks and storage capacity required to capture every last watt of excess production. As a result, some of the excess production from an oversized grid should be curtailed, or 'spilled'. Spilling sounds wasteful, but as storage and networks are both expensive and materials-intensive, some degree of oversizing is wise from both an economic and environmental perspective.[103] The modelling behind the ISP estimated the efficient level of curtailment in 2050 in the Step Change scenario is around 20 per cent, and other experts have suggested that even higher levels of overbuilding and spilling might be economic.[104 105]

Opportunities should be sought for productive uses for some of the energy that would otherwise be spilled, such as electrolysing hydrogen. However, there are likely to be limits to the volume of completely flexible load that could soak up excess generation, and substantial costs involved in building networks to transport excess energy from distributed generation to sites that might use it.

In an electricity system dominated by high levels of variable renewables, there is a necessary shift from assuming energy has high value at all times, to understanding energy is sometimes highly valuable, and sometimes almost a waste-product. This is fundamental to understand the changing role of smart energy use.

Overbuilding wind and solar will reduce the benefits of reducing energy demand when generation exceeds it. However a strategy for improving energy reliability that relies on overbuilding generation actually

101 Tong, D. et al 2021 'Geophysical constraints on the reliability of solar and wind power worldwide' *Nature Communications* volume 12, Article number: 6146.

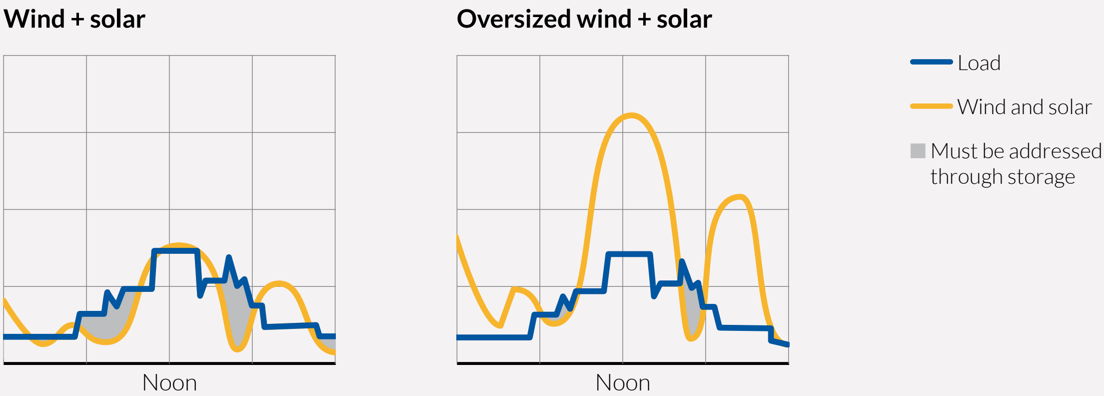
102 Wood, T. and Ha, J. 2021 *Go for net zero – A practical plan for reliable, affordable, low-emissions electricity*, Grattan Institute, Melbourne.

103 Perez, M. et al 2019 'Overbuilding & curtailment: The cost-effective enablers of firm PV generation', *Solar Energy* vol 180 pp412-422.

104 AEMO 2022 *Integrated System Plan – June 2022*, AEMO, Melbourne p.46.

105 Simshauser, P., Billimoria, F., Rogers, C., 2021. *Optimising VRE Plant Capacity in Renewable Energy Zones.* Faculty of Economics, University of Cambridge.

**Figure 6.4** Illustrative chart – overbuilding generation to reduce storage costs




Source: Derived from Houssainy, S. and Livingood, W. 2021 "Optimal strategies for a cost-effective and reliable 100% renewable grid", Journal of Renewable Sustainable Energy 2021, 13, Figure 1.

*increases* the benefits of reducing demand during pinch points. The degree to which we need to overbuild generation and invest in storage is determined by demand during critical periods (e.g. winters in the south, rainy seasons in the north). Reducing demand during those periods will reduce the amount of spending necessary on generation and storage.

## 6.7 Smart energy use and capacity

A reliable energy system needs to continuously balance supply and demand. This means our challenge is not so much a variation in the output of renewable generation, but the potential for a mismatch between supply and demand at certain times. For example, if renewable generators produce less energy during spring evenings when relatively little energy is being used, it is unlikely to present a challenge to reliability.

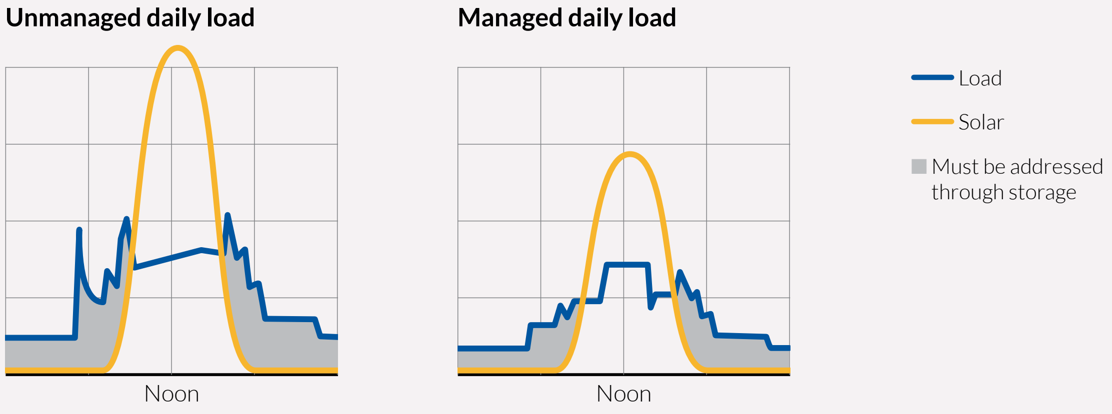
Challenges can arise when renewable generators produce less energy than demand, such as during hot summer evenings and in the middle of winter in southern states.

### Accordingly, *when* we save energy will have a substantial impact in a renewable energy system:

- Energy saving measures that *only* reduce demand during periods when renewable energy is plentiful will be of relatively low value to the system (although they may have other benefits, like comfort, health or productivity);
- Energy saving measures that save energy on a fairly consistent basis (e.g. fridge efficiency) will save some energy outside pinch points, which has limited value, but will also save energy during pinch points, reducing the investment needed in energy supply;
- Energy saving measures that predominantly save energy during pinch points will have a very high value per kWh of energy saved. For example, improving the thermal efficiency of a dwelling will primarily reduce demand during periods when solar isn't generating, which could have a significant impact on total system costs; and
- Shifting demand over short timescales from periods when energy is scarce to when it is plentiful (e.g. running water heaters during the day) may or may not reduce the amount of necessary supply-side capacity, but will reduce the dispatch of expensive storage and dispatchable capacity.

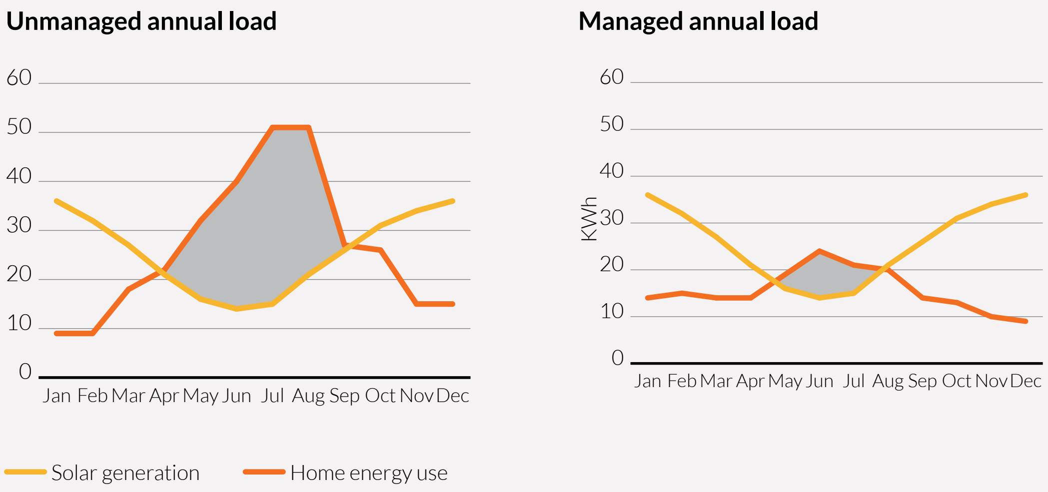
The following two figures show this through simplified examples of load management versus solar for an individual home over a day (Figure 6.5) and a year (Figure 6.6).

## Figure 6.5 Managing load to reduce expenditure on generation and storage (daily)




Source: Derived from Houssainy, S. and Livingood, W. 2021 "Optimal strategies for a cost-effective and reliable 100% renewable grid", Journal of Renewable Sustainable Energy 2021, 13, Figure 1

## Figure 6.6 Managing load to reduce storage requirements (annual)



Counter intuitively, reducing demand during key periods will actually increase the utilisation rate of renewable energy generation. If we do not reduce demand for energy in winter in southern states, we will have to build more generation to meet that demand, resulting in more energy being spilled over the rest of the year. In a 100 per cent renewable energy system, some degree of overbuild and spillage is inevitable, but managing demand during critical periods will reduce its extent, delivering better returns to renewable generation owners.

Examples of modifying demand to reduce the risk of pinch points include:

- Running electric water heaters that have hot-water storage tanks during the middle of the day, rather than at night, increasing the direct use of solar generation and reducing the amount of capacity we need from sources such as storage and dispatchable generation;
- Adjusting the charging time of EVs to match the output of renewable generation; and
- Retrofitting our homes with efficient heat pumps, insulation and draught proofing. In southern climates, cooling is needed in summer evenings and in winter, heating is needed in mornings and evenings. In tropical climates, higher cooling load is needed during the wet season. During these periods, general energy demand is higher and solar panels are producing far less energy. Improving the thermal performance of homes can significantly reduce their energy demand.

As with all technology options, there will be an optimum level for investment in energy management both at the individual and system level. For example, in many older houses in cold climates, an investment of less than $7,000 in insulation and draught-proofing can cut demand for energy in winter by over 30 per cent.

As a home becomes more efficient, the cost of additional efficiency gains will increase and incremental non-energy benefits (e.g. improved comfort) will decline, to the point that additional energy savings will cost more than additional storage.

A huge volume of energy savings are available in Australia far below the cost of energy storage or alternatives. Energy saving programs by utilities generally save energy at less than 3 cents per kWh, which is far less than the cost of storage.[106, 107, 108]

The ISP's 2022 Step Change scenario assumes significant improvements in energy efficiency; realising these gains will require the introduction of major new energy efficiency policies. However, there is potential to leverage energy efficiency well beyond what is contemplated in the Step Change Scenario, which would significantly reduce the cost of achieving the energy system transition.

Managing demand during critical periods has multiple benefits for our energy system as it reduces multiple costs, including generation, storage and networks.

**Managing demand is absolutely critical to the affordability of energy, and must not be an afterthought.**

## 6.8 Bringing it all together – optimising our energy system

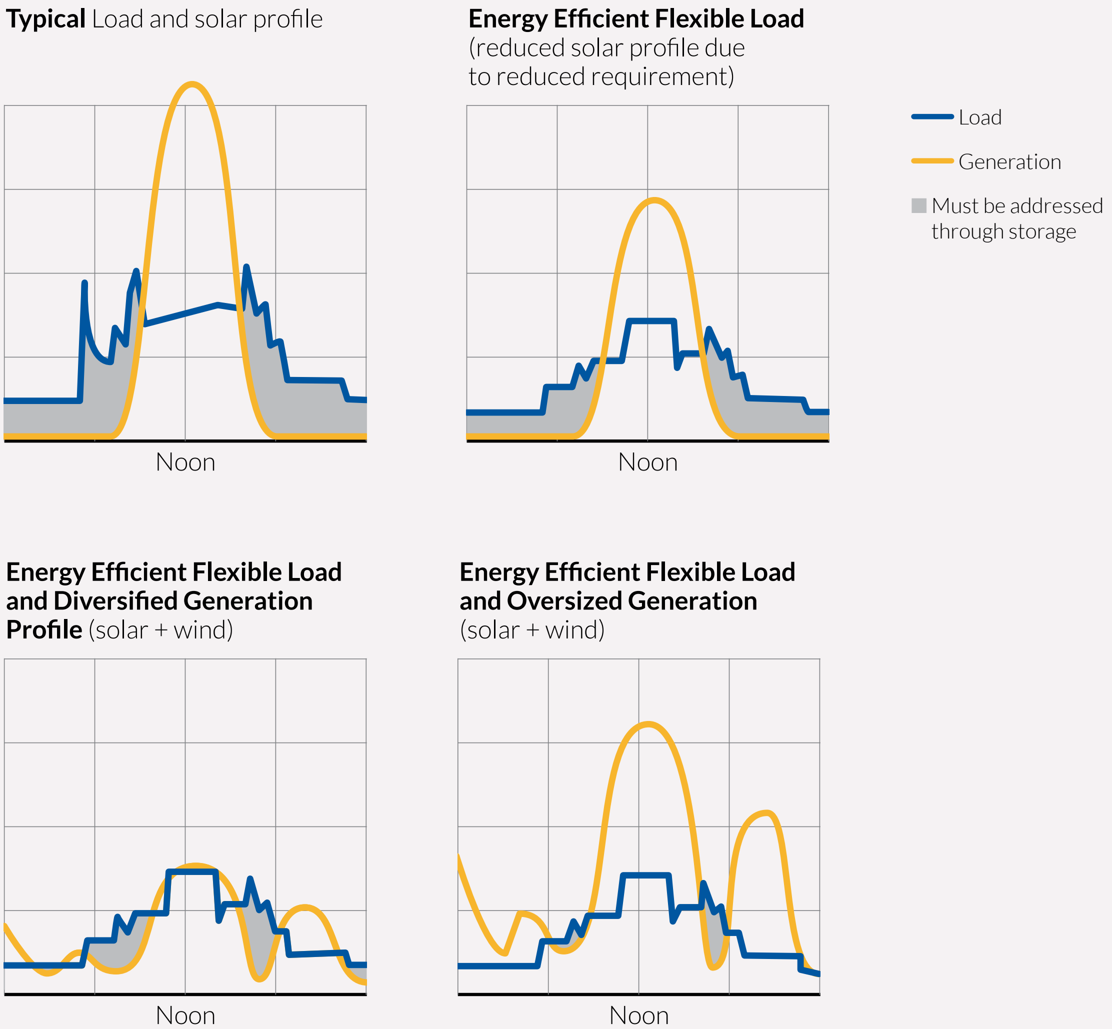
To build a reliable zero emission grid as affordably as possible, we need several integrated strategies, including energy management, diverse generation and overbuilding (Figure 6.7).

106 Nadel, S., Cowart, R., Crossley, D. & Rosenow, J. 2017, *"Energy saving obligations across three continents: contrasting approaches and results," Proceedings of the 2017 ECEEE Summer Study*, ECEEE, Stockholm.

107 Hoffman, I., Rybka, G., Leventis, G., Goldman, C.A., Schwartz, L., Billingsley, M., & Schiller, S. 2015, *The total cost of saving electricity through utility customer-funded energy efficiency programs: Estimates at the national, state, sector and program level*, Lawrence Berkeley National Laboratory, Berkeley.

108 International Energy Agency 2017, *Market-based Instruments for Energy Efficiency – Policy Choice and Design*, IEA, Paris.

**Figure 6.7** Combining strategies to minimise requirements for storage and dispatchable capacity




Source: Derived from Houssainy, S. and Livingood, W. 2021 "Optimal strategies for a cost-effective and reliable 100% renewable grid", Journal of Renewable Sustainable Energy 2021, 13, Figure 1.

In their previously referenced study, Houssainy and Livingood looked at how to deliver the lowest cost 100 per cent renewable energy system in various parts of the US.[109] They concluded that in most regions of the US, the most affordable strategy involved:

- Deep building energy efficiency measures resulting in permanent energy savings;
- Meeting demand using a mix of wind and solar that varied by region;
- Oversizing renewable generation; and
- Investing in energy storage to meet the residual demand for electricity.

Houssainy and Livingood's analysis is based on the US building stock, grid and climate conditions, and their technology cost assumptions may not apply in Australia. However, their paper sets out a robust framework for optimising an affordable zero-emission grid.

The EEC recommends governments build on the 2022 ISP with detailed analysis of energy saving opportunities to identify the most cost-effective mix of energy management, zero-emission generation, transmission, distribution and storage for Australia.

## 6.9 The narrow road to net zero

While this chapter considers balancing supply and demand as if these issues are static, they are not. The challenge isn't working towards balancing supply and demand in 2050, with all the low-cost technologies that may be available then. The challenge is balancing supply and demand every single day between 2023 and 2050, using the mix of cost-effective technologies available at that time.

The ISP Step Change scenario indicates that around 60 per cent of coal fired generation, around 14 GW, could withdraw by 2030.[110] If the pace of construction of 'firmed renewables' lags the pace of coal closure, it could create periods of high energy prices and potentially even periods of supply shortfalls. Australia has already seen this occur following the closure of the Hazelwood generator, when tightness in supply and demand put upward pressure on electricity prices.[111]

To address the risk of supply shortfall, governments should accelerate the development of firmed renewable capacity. However, there are significant risks that investment in generation, storage and networks may not be able to keep pace with both the closure of coal-fired generators or increase in electricity demand associated with an electrifying economy. For example, Snowy Hydro 2.0 and several of the transmission projects identified in the ISP are well behind schedule. There is also the risk that hydrogen, batteries and EV's as grid storage do not fall in cost at the hoped-for rate.

Given firmed renewable capacity may not develop as fast as necessary, governments have also sought to delay the closure of coal-fired generators to ensure there is always sufficient capacity in the NEM. While preventing some generators going either temporarily or permanently off-line may be prohibitively expensive or impossible, this decision will slow the decline in Australia's emissions (see chapter 3). As coal-fired generators age, they start to develop problems that can be very hard to remedy. These issues have been on display throughout 2022, with significant outages from coal fired plants contributing to periods of exceptionally narrow supply-demand balances in the middle of the year in eastern Australia.[112]

109 Houssainy, S. and Livingood, W. 2021 "Optimal strategies for a cost-effective and reliable 100% renewable grid", *Journal of Renewable and Sustainable Energy* 13, 066301.

110 AEMO 2022 *Integrated System Plan – June 2022*, AEMO, Melbourne.

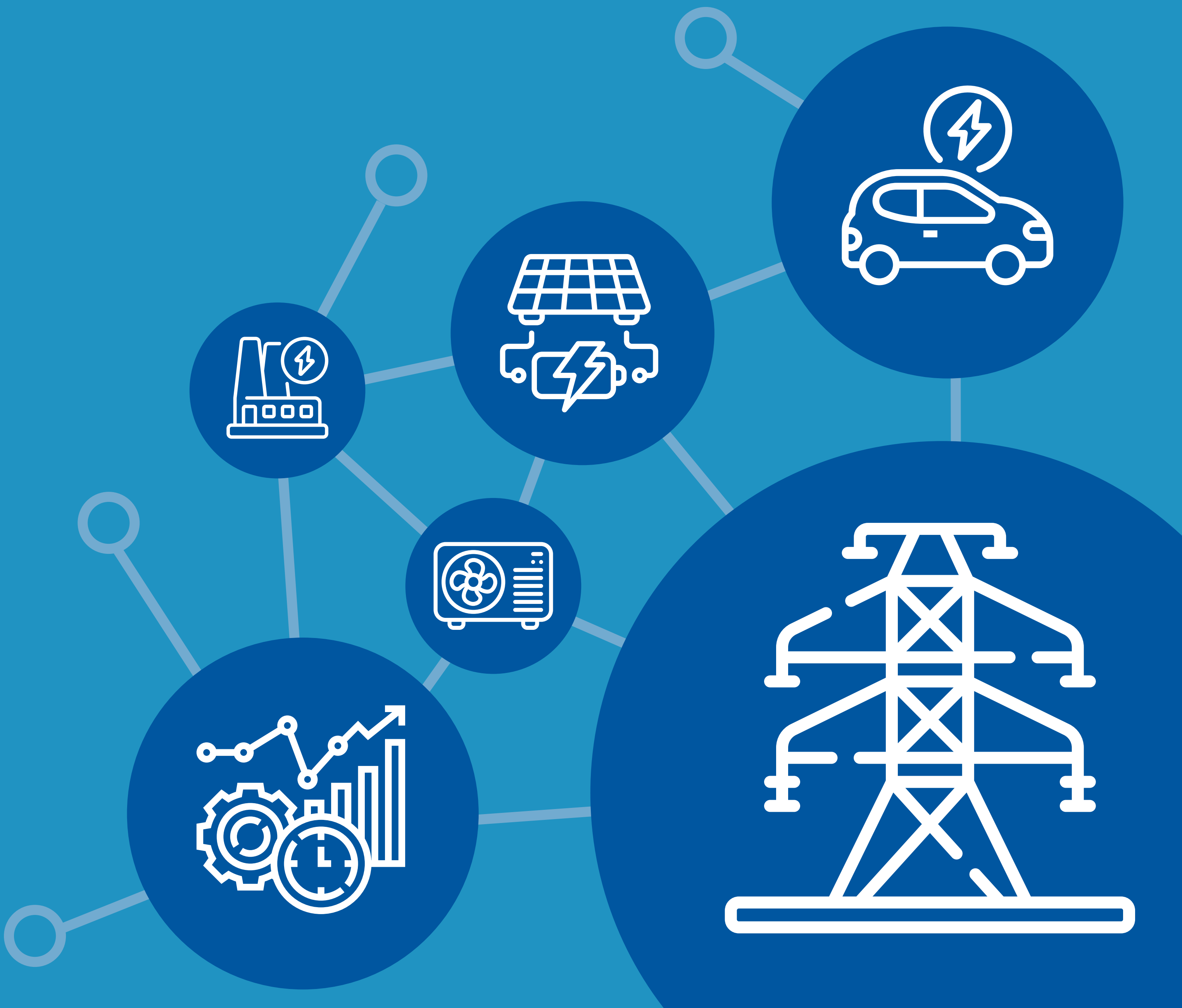
111 Australian Energy Regulator 2018 *AER electricity wholesale performance monitoring – Hazelwood Advice – March 2018*, AER, Canberra.

112 Australian Energy Market Operator 2022, *Q2 Quarterly Energy Dynamics*, AEMO, Melbourne.

Development of firmed renewable capacity is an urgent priority, but EEC strongly recommends that governments also work to reduce demand during critical periods. In particular, we need to ensure that when homes, businesses and vehicles are electrified, it is done so in a way that minimises the additional demand placed on the grid during pinch points. Energy management generally involves mature technologies, including insulation, air tightness and heat pumps, which means it is a dependable complement to investments in technologies such as renewables and storage.

Reducing demand at the same time investments are made in generation, storage and networks will both reduce the cost and risk of transition. It is not enough to wait until 2040 to optimise the mix of investments in energy management, electrification, renewable generation, storage and networks. All these strategies must be pursued in tandem to ensure energy reliability and affordability.

# 07 Networks, system security and smart energy use



## Summary

This chapter examines the role of electricity networks in the clean energy transition, and the importance of keeping networks affordable. Reducing demand at key times will be critical to reduce the amount spent on network augmentation.

## 7.1 The role of the grid

The previous section looked at ensuring energy supply and demand are continuously matched. Just as critical is having an affordable network that can transport energy to consumers. Connecting energy users to the grid makes it easier to achieve clean, reliable and affordable energy:

- **Diversity of generation:** Networks connect users to a diverse mix of generation types and locations, which increases the consistency of supply.
- **Diversity of load:** Energy users don't have identical energy use patterns, and combining many energy users will generally result in a flatter and more consistent pattern of energy use. A more even pattern of energy use can generally require less supply to service it.
- **Economies of scale:** Utility-scale windfarms and grid-scale storage generally have a far lower cost per customer than small-scale wind turbines and household storage.

Off-grid homes that are only supplied by solar PV and batteries would need to invest very large amounts in generation and storage to ensure reliable energy supply, especially in southern regions that have a significant winter heating load. As a result, it is extremely rare to find an off-grid home that solely relies on solar and batteries. Most off-grid homes in Australia are both energy efficient and use a range of strategies to meet their energy demand that would be hard to scale to the whole country, including using:

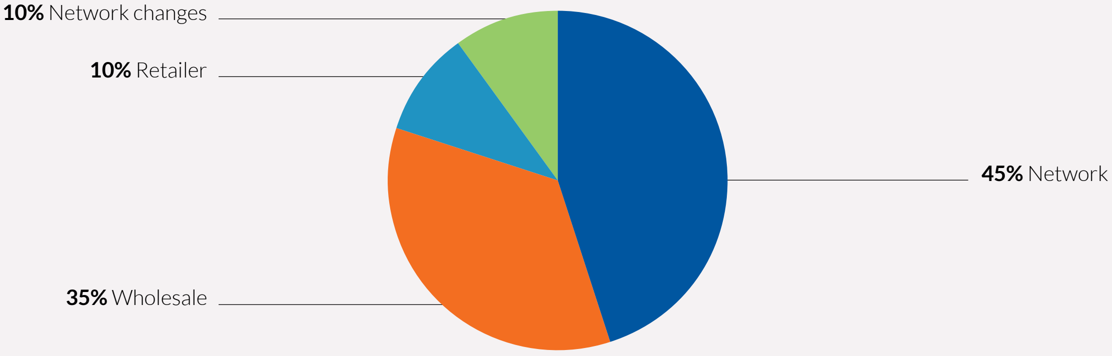
- Firewood for winter heating. Widespread use of woodfires, especially in urban areas, would result in unsustainable rates of wood consumption and significant air pollution;
- Liquified Petroleum Gas (LPG) cylinders for heating and cooking. This is both high emissions and high cost; and
- Back-up generators that run on fossil fuels.

In some locations, such as remote sites, the cost of connecting to a grid is so high it makes sense to be off-grid. However, for the vast majority of energy users in Australia (well above 90 per cent) it will be far cheaper to be connected to the grid. In urban areas, energy users would most likely connect to the main grid, but in an increasing number of regional locations it might make sense to connect to a regional microgrid, such as on King Island or isolated towns in regional Western Australia, that have no or limited connection to a larger grid.

Evidence suggests the pathway to a fully decarbonised energy sector will be far more cost-effective and equitable if the majority of energy users remain connected to the grid. However, there is a significant risk that many energy users will exit the grid if it does not provide the clean, reliable and affordable energy they demand. When wealthier energy users exit the grid, it not only means these households over invest in storage and generation, it also increases grid charges for the people still connected– a worse outcome for everyone.

**In other words, we need to keep the grid as clean, reliable and affordable as possible to incentivise people to stay connected.**

**Figure 7.1** The typical components of a household electricity bill




Source: Australian Energy Market Commission 2022 Spot and Contract Markets. AEMC, Sydney. Accessed online on 2 August 2022 from https://www.aemc.gov.au/energy-system/electricity/electricity-market/spot-and-contract-markets.

## 7.2 Keeping the grid affordable

While grids deliver valuable services, they are not cheap to build. Over the last decade, charges for the network (poles and wires) have been the single largest component of household electricity bills, typically accounting for between 40 and 50 per cent of a household bill. Network charges are largely repayments to monopoly Network Service Providers (NSPs) for capital invested in the grid. To keep the grid affordable, we need to limit further investment in the grid to that which is absolutely necessary. (Figure 7.1)

The impact of network expansion on electricity bills has been well demonstrated. Between June 2007 and December 2012, average electricity prices in real terms increased by 70 per cent.[113] While many commentators blamed the introduction of a carbon pricing mechanism, the main culprit in most states was a very large increase in network charges resulting from expenditure on the grid. Network charges for an average NSW household bill increased an astonishing 130 per cent between 2007-08 and 2012-13 (Figure 7.2).[114]

While some investment was necessary, there are legitimate questions as to whether regulatory processes designed to contain capital expenditure in monopoly network infrastructure took an appropriately rigorous approach to assessing the merits of proposed network investments. While there have been significant efforts to address a previously laissez-faire approach to monopoly NSP regulation, there is still much work to be done.

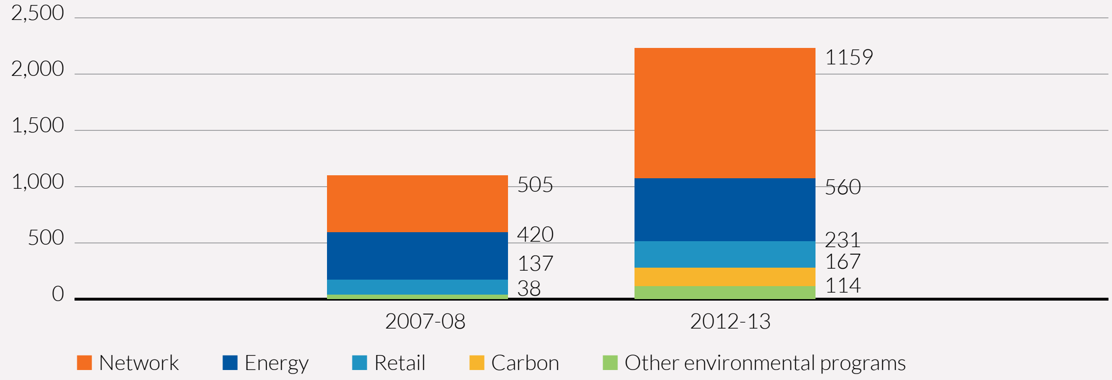
Heeding the lessons from the 2008-13 period and applying them to developing a 100 per cent renewable grid involves:

- Accepting that significant investment in transmission networks is necessary to connect renewable generation and load centres;

113 Productivity Commission 2013, *Electricity Network Regulatory Frameworks, Report No. 62*, Canberra p2.

114 Ibid p14.

**Figure 7.2** Average NSW electricity bill in 2007-08 and 2012-13




Source: Productivity Commission 2013, Electricity Network Regulatory Frameworks, Report No. 62, Canberra

- Understanding that network costs are a major driver of energy bills. Australians will end up paying very high electricity bills if we *over invest* in transmission and distribution networks to eliminate spillage or link every renewable generator proposed by a household or business; and
- Very carefully assessing the merits of every grid investment. Where there are opportunities to avoid investment in transmission and distribution grids, these opportunities should be taken.

## 7.3 Avoiding over investment in the grid

The role of NSPs isn't to build poles and wires *per se* – it's to ensure energy users have reliable access to the energy services they need. This means there are a range of supply-side and demand-side options that can be used to minimise further investment in poles and wires, including distributed generation, storage and energy management.

Most parts of Australia already have mature networks, and further investment in them can be reduced by minimising growth in *peak flow* through the grid. With increased prevalence of distributed generation and storage, customer demand for energy is partly or sometimes fully met by onsite resources, which can reduce the loads on the grid.

In locations with distributed generation, peak flow will occur when onsite resources of multiple consumers in a region are not able to meet their demand for energy.

This could occur during summer evenings, particularly in areas with limited distributed storage, and during winter even in regions with plentiful storage.

The challenge is that reducing the average load on the grid, whether through onsite renewables, storage or energy efficiency, may not have any impact on peak flow through the grid, and will therefore not put downward pressure on grid costs.

For example, if a home adds onsite generation and storage and doesn't draw from the grid for 90 per cent of the year, but still draws during peak times in winter, it may not alleviate the pressure that individual home puts on the grid.

This means focus must be placed on reducing demand for energy at critical periods to reduce pressure to expand the grid. Happily, a number of the actions outlined in Chapter 6 to avoid mismatches in supply and demand also help address peak flow:

- Reducing demand during pinch points through increases to home thermal performance, water heating efficiency and EV efficiency;
- Timing EV charging and water heating to minimise localised peak flows; and
- Demand response by businesses.

Critically, the grid is not a uniform environment. There are parts where congestion will limit energy inflows and outflows, particularly within the distribution network. This means there will be both localised periods of low generation and localised curtailment – sometimes simultaneously. The costs – and physics – of grid infrastructure mean some level of localisation is far more cost-effective than having a high-capacity grid that perfectly connects every part of the country. The costs and benefits of managing demand to minimise network investment will vary significantly based on very local issues.

**A key conclusion from this report is that to minimise overinvestment in the grid, Australian governments and market bodies should invest in independent research to better understand the costs and benefits of grid augmentation at a granular level in the transmission and distribution network.**

In particular, Australia needs a far better understanding of the options to ensure grid augmentation is efficient and well targeted.

## 7.4 Using energy management to reduce network costs

NSPs can theoretically invest in measures that reduce demand and the need for capital expenditure (capex) on networks. For example, Energex in Queensland runs the 'PeakSmart' program, giving households an incentive of up to $400 in exchange for modulating the output of their air conditioner when the grid is under stress.[115]

However, until recently NSPs were incentivised to over-invest in networks, and disincentivised from reducing demand if it reduced capex. These misaligned incentives have been partially rectified by a raft of changes to NSP regulations, including the Demand Management Incentive Scheme (DMIS) and Demand Management Innovation Allowance (DMIA). However, NSPs still do not face strong incentives to invest in demand-side measures that reduce capex, and their skill-sets still favour building network infrastructure. To address this, the EEC recommends setting NSPs a minimum target for demand-side investments as a proportion of their investment.

While energy users and energy service companies could invest in energy management that reduces the need for network expenditure, they would be unlikely to be properly remunerated for these investments. NSPs are regional monopolies, and under our current system, sellers of energy services are not guaranteed to secure a fair price for the capacity they deliver. To address this barrier, the EEC recommends the establishment of markets for demand-side capacity, potentially with a central buyer that stands independent from NSPs.

115 Energex 2023 *PeakSmart Air Conditioning rewards*. Accessed online on 9 March 2023 from *https://www.energex.com.au/home/control-your-energy/cash back-rewards-program/air-conditioning-rewards*.

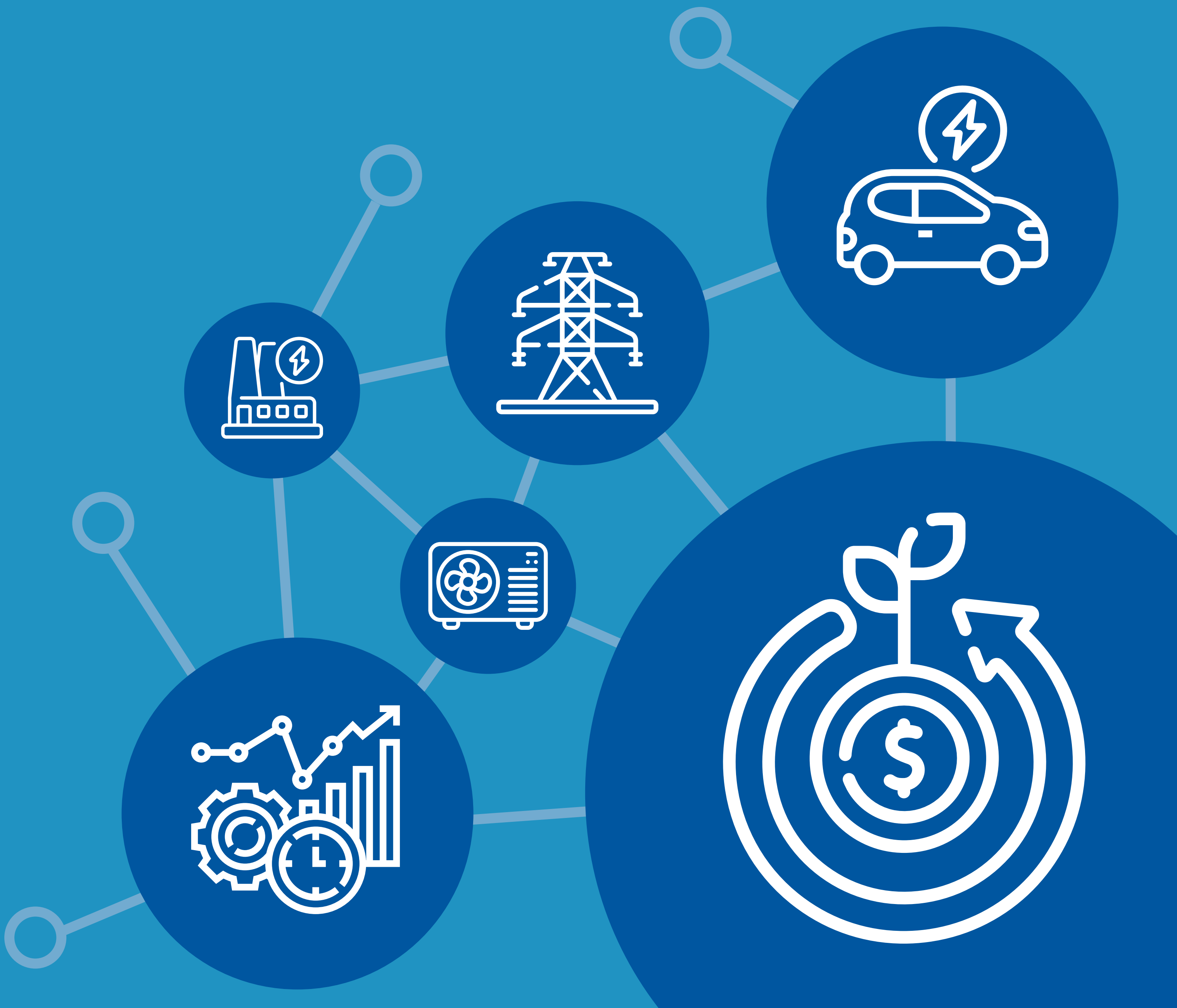
## 7.5 Grid security

To function, a renewable energy grid will also need a range of services, including:

- A frequency of 50 hertz. Frequency control requires supply and demand to be balanced across very short time periods. These can then be divided down into different time periods of frequency control response, from the almost instantaneous and automatic response (often referred to as inertia) to periods of fractions of seconds, seconds and minutes, which operate according to dispatch instructions; and
- Avoiding over-supply. As noted earlier, a reliable renewable energy grid is likely to have periods when generation output could vastly exceed both demand and storage capacity. This issue is sometimes called 'minimum demand'.

Demand response already plays a key role in frequency control, and could play a more significant role in dealing with minimum demand, as loads can be adjusted up during periods of over-production.

# 08 Delivering affordable energy services



## Summary

This chapter examines the necessary reforms to make energy affordable. Correcting supply-side biases in Australia's energy systems and improving policy coordination will result in the most cost-effective mix of generation, storage, networks and demand-side investments.

## 8.1 Minimising total cost of energy services to society

The provision of electricity services (e.g. cool homes in summer) involves investment in a combination of generation, storage, networks, buildings and energy-using equipment. Minimising consumer costs will require investment in the mix of supply- and demand-side measures that deliver the lowest total cost to society for energy services.

To explore this concept, we can look at an all-electric off-grid home. As noted in chapter 7, in most parts of Australia it is far more cost effective for homes to connect to the grid, but a simplified off-grid model can be illustrative. Home A has inefficient water heating, lacks insulation and is draughty, meaning a large amount of money is required for an air conditioning system with sufficient capacity to warm the house in winter and cool it in summer, and a larger amount is required for solar panels and storage. In Home B, a modest investment in a more efficient water heater, insulation and draught proofing substantially reduces the capacity and cost of the air conditioning system, solar and batteries (Figure 8.1).

**Of the two, the more efficient home (Home B) is clearly the better option. Not only will it be more comfortable than Home A, its capital cost is substantially lower.**

Generally, the best option for affordable energy services for an off-grid home will involve some investment in energy management, energy supply and storage. Underinvestment or overinvestment in any of these options will lead to higher costs for the household.

The goal is roughly the same for electricity grids: getting the best mix of investments to deliver reliable energy services. However, the problem is far more complex for two primary reasons. First, supply and demand are being optimised across millions of pieces of equipment, with new elements constantly being added to the system. Second, the attempt to coordinate investments is split between multiple parties, explored more in Section 8.2.

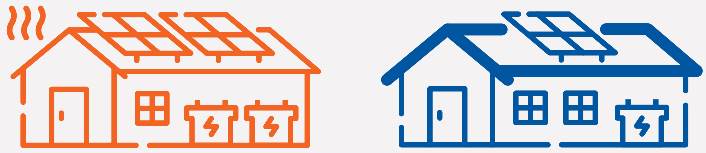
'Total cost for society for energy services' is a powerful metric to assess the current and, especially, future affordability of the electricity system.[116] While metrics such as 'price per unit of electricity' (e.g. cents per kilowatt-hour (c/kWh) have a useful role in assessing affordability, they should not be the primary affordability metric . There are several reasons for using total cost for energy services as the primary metric, particularly when trying to model the future.

First, the vast majority of households care about the total cost of their energy bills, not the price per unit (Figure 8.2). For businesses, the most relevant metric is generally cost of energy per unit of production, not c/kWh. Energy bills are not only a function of the price per unit of energy, but also the number of units consumed. Most consumers will be happier to pay $60 per month to efficiently use electricity at 25c/kWh, than $100 a month to inefficiently use electricity at 20c/kWh. If we focus on c/kWh as the sole metric of affordability, it can lead to perverse outcomes, such as discouraging efficiency to increase utilisation rates of the network in ways that would not actually reduce bills.

Second, electricity bills are generally not only a flat c/kWh consumption charge, but often include a periodic charge (e.g. per day) and sometimes a charge for maximum demand. This is partly because a flat c/kWh charge can be a poor reflection of the cost of providing many types of energy service. For generation, the cost of supply varies across time. For networks, their function is reliable connection, and the cost of providing this service is affected by peak flow at specific times, which is not necessarily related to consumption. As the proportion of sites with distributed solar and storage increases, a consumer's annual draw from the grid will become an increasingly poor proxy for their draw from the grid at peak times.

116 Byrom, S. et al 2021 "Total Systems Cost: A Better Metric for Valuing Electricity in Supply Network Planning and Decision-Making", *Journal of Environmental Informatics Letters*, 6(2).

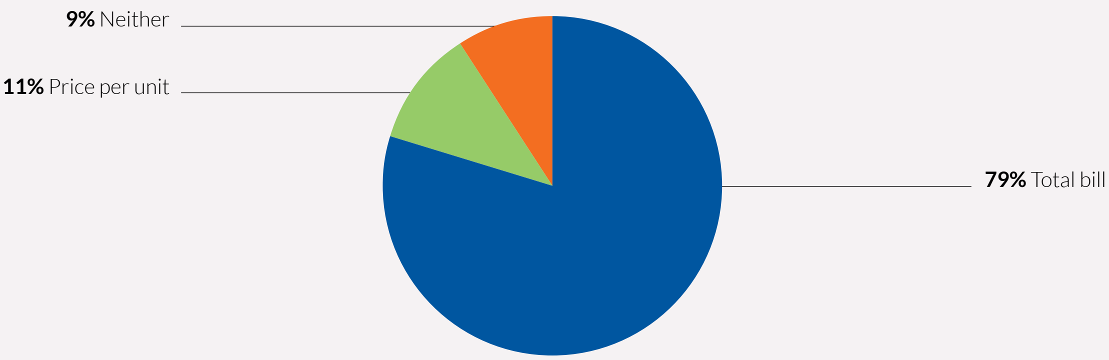
## **Figure 8.1** Illustrative comparison of two theoretical off-grid homes



| | Home A | Home B |
|---|---|---|
| **Ceiling insulation** | No | Yes |
| **Draught proofing** | No | Yes |
| **NatHERS rating** | 1.5 | 3.2 |
| **Reverse cycle** | 15.5 kW | 10 kW |
| **Water heater** | Resistive | Heat Pump |
| **Demand on an average July day** | 42 kWh | 25 kWh |
| **Solar panels** | 32 kW | 20 kW |
| **Batteries** | 62 kWh | 31 kWh |
| **Total cost** | $121,190 | $82,990 |

This figure is illustrative, as most off-grid homes are very efficient and have back-up generators to minimise solar and battery costs. This figure is based on a simplified off-grid 160m² house in the Melbourne climate zone, and only costs the elements listed. Light House Architecture and Science estimated energy demand and Pure Electric estimated solar and battery system requirements.

## **Figure 8.2** Proportion of surveyed households that care about their total energy bills versus price per unit of energy




Source: ACOSS, EEC and the Property Council of Australia, EEC 2018 *Energy bills and energy efficiency – a survey of community views by YouGov Galaxy*, ACOSS, Sydney.

This highlights that there isn't necessarily a 'natural' way to pass on the cost of the energy system to consumers. Tariffs are designed to balance a number of factors, including cost-reflectivity, simplicity, equity and providing a degree of stability to the energy sector to encourage investment. Given the dramatic change underway in our energy markets, we cannot make assumptions about how costs will be passed on to consumers in future. When considering future energy systems, there are less assumptions involved in simply projecting total costs for energy services, and knowing these costs will be passed on to consumers in some form.

However, how we distribute the costs of energy to consumers is critically important. 'Affordability' is not simply determined by the size of the average energy bill, and is affected by both variation in energy use and variation in energy users. High income households typically spend significantly less than 3 per cent of their income on energy bills, while low income households can spend over 8 per cent of their disposable income on energy bills.[117] Therefore, in thinking about a future energy system, we must think both about minimising total system costs to society, and how to distribute those costs fairly.

## 8.2 Energy market design

In the electricity system, rules and regulations attempt to optimise investments in both supply- and demand-side measures. These investments are undertaken by multiple parties, including:

- Electricity consumers (households and businesses), who generally have primary responsibility for decisions regarding investment in, and use of, anything on-site and 'behind the meter.' This includes generation, storage, buildings and energy-using equipment;
- A broad range of companies producing and selling equipment and services that impact consumer energy use, such as appliance manufacturers, builders and home energy assessors;
- NSPs, responsible for ensuring consumers are connected to reliable energy supplies;
- Private companies and governments investing in utility-scale generation and storage; and
- Electricity retailers bundling network and generation services, for which they charge customers. Some retailers also provide energy management services, particularly to business customers.

Markets and other systems have been designed by governments to try to optimise investment in electricity services across these parties.

**As electricity is an essential service that involves monopoly networks, governments do not have a choice about *whether* to regulate electricity markets. The question is *how* they regulate those markets.**

At present, this includes regulation of NSPs, extensive regulations around electrical safety and system stability, and wholesale spot-prices and dispatch decisions made by a central buyer based on a set of rules and assumptions.

The balance of investment in supply- and demand-side measures is affected by electricity market design. As mentioned earlier, multiple reviews have identified a supply-side bias in our energy markets. The 2002 *Energy Market Review* (known as the Parer Review) conducted for the Council of Australian Governments states:

"The Panel found that there is a relatively low demand side involvement in the NEM because:

- the NEM systems are supply side focused
- the demand side cannot gain the full value of what it brings to the market
- residential consumers do not face price signals." [118]

117 ACOSS and Brotherhood of St Laurence 2018 *Energy Stressed in Australia*, ACOSS, Sydney.

118 Parer, W. 2002 *Council of Australian Governments Energy Market Review – Towards a Truly National and Efficient Energy Market*, Commonwealth of Australia, Canberra. p174.

In the 20 years since this review, numerous others have confirmed the existence of these distortions, and some efforts have been made to resolve them.[119 120 121] To date these efforts have been piecemeal and insufficient, and the supply-side bias is still significant. A major wave of investment in the energy sector is being driven by greenhouse emission reduction targets, fuel costs, technology developments and consumer preferences.

If the correct balance is not achieved in this new wave of investment, billions of dollars will be wasted, reducing Australia's productivity.

## 8.3 Correcting the supply-side bias

Individuals within Australia's energy institutions and markets have on occasion gone above and beyond their responsibilities in attempts to correct the supply-side bias, as they see significant public benefit in doing so. Faced with a systemic bias permeating governance arrangements, market design, policy design and implementation of regulations, these individual efforts need system-wide support.

Australia is not the only country that faces systemic supply-side bias. Electricity markets around the world have traditionally focused on building energy supply, with demand seen as something to forecast, rather than something that can be influenced.[122] To address this bias, governments in the US and European Union have adopted explicit principles that attempt to ensure that governance, policies and investments deliver the most cost-effective mix of supply- and demand-side measures.

In the US, 38 states require vertically-integrated utilities to undertake processes alternatively called 'integrated resource planning' or 'least cost planning'.[123] Integrated resource planning involves forecasting future demand for energy; identifying potential supply- and demand-side options; and determining the mix of supply- and demand-side measures that will meet consumer demands at lowest cost.

The European Union has adopted the principle of 'Energy Efficiency First', which, despite its confusing name, has a similar goal to integrated resource planning, namely, investment in the least cost mix of supply- and demand-side measures. However, unlike integrated resource planning, Energy Efficiency First recognises and attempts to address the many biases against demand-side investment that lie outside monopoly utilities.

119 Department of Climate Change and Energy Efficiency 2010 *Prime Ministers Task Group on Energy Efficiency – Final Report*, Commonwealth of Australia, Australia.

120 Australian Energy Market Commission 2012 *Power of Choice – Stage 3 Demand-Side Participation Review*, AEMC, Sydney.

121 Finkel, A. et al 2017 *Independent Review into the Future Security of the National Electricity Market*, Commonwealth of Australia, Canberra.

122 Murray-Leach, R. 2019 *The World's First Fuel*, Energy Efficiency Council, Melbourne.

123 Wilson, R. and Biewald, B. 2013 *Best Practices in Electrical Utility Integrated Resource Planning*, Regulatory Assistance Project, Brussels.

The Regulatory Assistance Project, an independent advisory body to energy regulators and policymakers, has recommended governments take action on multiple levels to implement Energy Efficiency First, including:

- Updating governance arrangements to ensure key institutions have the remit to consider both demand- and supply-side measures;
- Reviewing energy market design and climate change policies to ensure they consider both energy supply and demand; and
- Requiring electricity system planners, regulators and NSPs to consider whether demand-side options can help meet communities' energy needs before they plan, approve or invest in supply-side infrastructure.[124]

The EEC recommends that Australian energy ministers adopt a principle similar to US and European governments, called by the more accurate title; 'least cost energy services.' In addition to adopting this high-level principle, ministers should update the National Electricity Objective (NEO) to clarify its affordability objective.

To enact the 'least cost energy services 'principle, government departments and energy market bodies should follow the steps outlined by the Regulatory Assistance Project, and review and, where necessary, make changes to governance, policies and investments. In particular, organisations should invest in detailed studies to support least-cost energy services. AEMO should be supported to expand its ISP with detailed analysis of energy saving opportunities to identify the most cost-effective mix for Australia of energy management, distribution networks, transmission networks, zero-emission generation and storage.

124 Bayer, E. 2018, *Energy Efficiency First: A Key Principle for Energy Union Governance*, Regulatory Assistance Project, Brussels.

## 8.4 Consumers cannot optimise demand on their own

Despite the obvious supply-side biases in our energy markets it has been argued that governments and energy market bodies should have minimal involvement in optimising investment between supply-side and demand-side measures, as energy consumers will take action in response to price signals. There are a number of substantial problems with this argument, including:

- Tariffs are not particularly cost-reflective for households and small-business customers;
- There are a range of capital, expertise and information barriers for customers that prevent optimum investment in either supply- and demand-side measures, but…
- Governments set up energy market structures so experts could make supply-side decisions on behalf of consumers without customers having to find the capital or knowledge to do so. There has been no equivalent effort to remove the need for consumers to find capital, expertise and time to manage energy use, reinforcing the fundamental supply-side bias; and
- Many investment decisions in the energy market are undertaken on behalf of consumers. For example, monopoly NSPs invest on behalf of consumers, meaning consumers are not in a position to adjust the balance of investment between supply- and demand-side measures.

As noted earlier, households and small businesses are currently charged for electricity services through tariffs that are not particularly cost reflective. While wholesale electricity costs are relatively reflective of cost, network charges vary between NSPs, and some are not cost reflective at all. While some retailers directly pass on wholesale energy prices to consumers, most retail tariffs significantly flatten both wholesale and network costs, and completely flat 'daily charges' have become an increasing proportion of many bills.

While the cost of meeting energy demand varies dramatically over time and space, the vast majority of consumers do not currently see these prices and are not incentivised to invest in the optimum mix of generation, storage and energy management. With the increased penetration of solar, there is a sensible debate about lowering energy tariffs in the middle of the day and increasing tariffs at night, which will improve price signals. However, few people are seriously proposing mandating of *fully* cost-reflective tariffs, where costs would vary continually by time and location.

While the EEC strongly supports improving price signals, we do not believe mandating price signals that perfectly reflect both the time and location of energy use are either politically possible or desirable. First, there are other factors to consider in tariff structures, including equity and simplicity. Second, most consumers are not particularly responsive to complex price signals. Third, price signals, on their own, don't solve all coordination issues.

Therefore, while the EEC supports a consumer-led process to develop a national set of 'best-practice' tariff structures for networks (to minimise the effort required in consumer representatives engaging in multiple complex tariff determinations) we think it is far more important to focus on non-tariff mechanisms to encourage investments and practices that benefit energy consumers in the long term.

## 8.5 Markets for demand-side services

Energy consumers can provide a range of services to energy markets, including:

- **Reduced wholesale electricity prices:** reducing demand at certain times can provide low-cost capacity that reduces the need to build or dispatch more expensive generation;
- **Reduced network costs:** reducing demand at certain times can reduce the need for network augmentation;
- **Emergency capacity:** during rare events, supply can be much lower due to problems with network and/or generation. If customers – particularly businesses – reduce their non-essential energy use during these periods, system stability can improve and reduce the need for involuntary load-shedding; and
- **FCAS:** a rapid change in supply or demand can change the frequency of the grid, threatening grid stability. If customers respond to incentives and voluntarily change their demand, it can bring the frequency back to around 50 Hertz, stabilising the grid.

As noted in the Parer Review, consumers are not properly incentivised to provide most of these demand-side services. Consumers generally pay relatively flat electricity tariffs that do not properly encourage them to reduce demand during periods of very high wholesale prices, or precisely target periods of network constraints. Adding further complexity, the times when wholesale prices are high, and networks are most constrained, may not be the same times that high wholesale prices and network constraints would occur in a heavily-electrified and all-renewable country.

The solution to these problems is to create markets for relevant services. In 2015 the Australian Energy Market Commission passed a rule change allowing demand response and batteries to provide FCAS. As a result, these resources now provide a significant proportion of FCAS, and have contributed to a rapid drop in the price for FCAS. The impact of this rule change demonstrates the power of price-signals and open markets for delivering a step-change in energy management and lower prices for bills.

The Australian Energy Market Operator also runs a Reliability and Emergency Reserve Trader (RERT) that purchases capacity for emergencies, including demand response. On 24 October 2021, it launched the Wholesale Demand Response Mechanism (WDRM) which allows demand-response providers to bid in capacity to the wholesale market. While both RERT and the WDRM have increased demand-side participation, many customers have been unable to participate due to a lack of suitable baseline methodologies.

It is important to resolve these issues, and these problems highlight the importance of getting the details right in effective markets. It will be particularly important to ensure the demand-side can participate in emerging markets such as the Australian Government's proposed capacity mechanism.

Finally, it is clear neither NSPs nor energy users are well incentivised to make investments that reduce the need for network augmentation. The EEC proposes that governments review whether to establish regional competitive markets for network capacity, so network infrastructure and demand management can compete on a level playing field. This would both increase competition and reduce the need for expenditure on the electricity network.

In summary, demand-side services have often not been allowed to compete with supply-side investments in markets for energy services, creating a substantial bias that increases consumers' energy costs. Reforms that allow demand-side services to fairly compete with supply-side investments in markets for energy services will deliver lower costs to consumers.

## 8.6 Measures outside energy markets

Beyond energy markets, many factors influence household and business energy use.

Changes in the supply chains, markets or regulatory environments for sectors such as construction and vehicles can intentionally or unintentionally enable, support or challenge improvements in energy management.

Australian governments have introduced a number of programs outside of energy markets that explicitly aim to improve energy efficiency. These include:

- The Commercial Building Disclosure program, requiring the disclosure of energy efficiency ratings for office spaces over 1,000 square meters when sold or leased. This program has played a key role in the energy use in regulated offices falling over 50 per cent per square meter in the past decade;[125]
- Minimum energy efficiency requirements for the construction and major renovation of new buildings in the National Construction Code;
- Minimum energy efficiency requirements for selected appliances under the Greenhouse and Energy Minimum Standards (GEMS) program; and
- Energy efficiency obligation programs, which require energy retailers to invest in a certain volume of certified energy efficiency activity.

While these programs have delivered significant benefits to Australians, we haven't tackled all major barriers to energy management in Australia. As noted in Chapter 2, Australia was ranked as the as the worst developed country for energy efficiency policy and practice out of the 25 largest energy-consuming countries in the world.[126] This means Australia could save a huge amount of energy simply by adopting well-proven technologies, practices and policies from other countries (Figure 8.3).

The EEC strongly recommends that Australian government aim to match other global leaders on energy management. Key priorities should include:

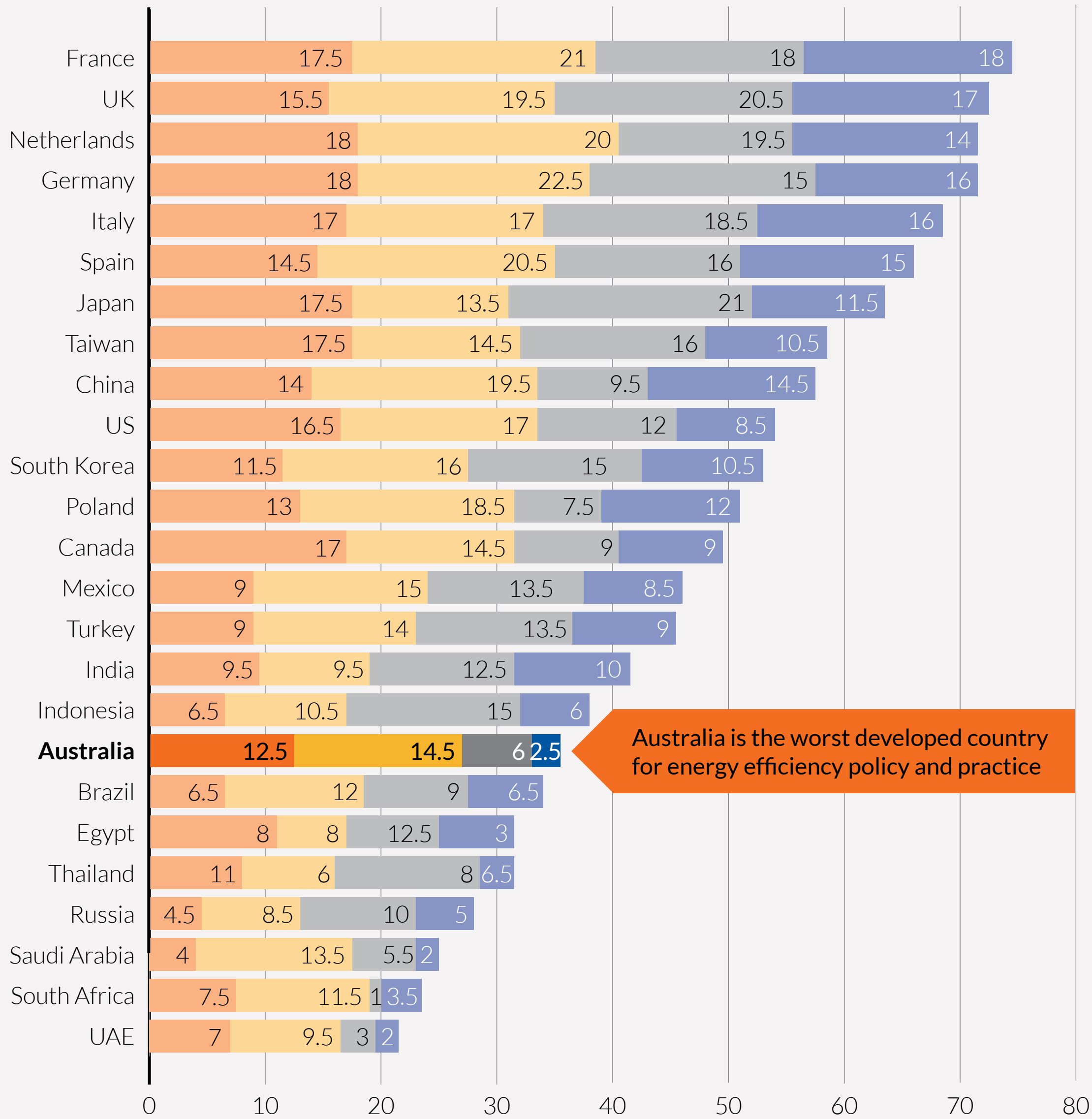
- Bringing all existing homes up to at least a basic level of energy efficiency for heating, cooling and hot water. Improving the performance of our worst homes will not only deliver substantial cost savings, but even more substantial health benefits; and
- Supporting businesses to adopt energy management systems and invest in the development and demonstration of key technologies for electrification and efficiency; and
- Setting minimum energy efficiency standards for critical technologies. Millions of heat pumps and vehicles will be purchased in coming decades. Setting robust standards for this equipment will be critical to ensure we electrify efficiently.

We also recommend that governance reform is undertaken to better coordinate policy work impacting energy supply and energy demand, potentially including the establishment of a new national organisation to lead on energy management. A diverse range of organisations work on issues like energy markets and minimum efficiency standards for buildings, and stronger coordination between these organisations will support the lowest cost for energy services.

125 NABERS National Administrator, *2022 NABERS Annual report 2021-22*, Government of NSW, Sydney. Accessed online on 28 February 2023 from: https://nabers.info/annual-report/2021-2022/office-energy/

126 American Council for an Energy Efficient Economy 2022 *International Energy Efficiency Scorecard 2022*, ACEEE, Washington DC

**Figure 8.3** 2022 International Energy Efficiency Scorecard




Source: American Council for an Energy Efficient Economy 2022 *International Energy Efficiency Scorecard 2022*, ACEEE, Washington DC

# Acronyms

**AEMO** Australian Energy Market Operator

**BEV** Battery electric vehicle

**EEC** Energy Efficiency Council

**EV** Electric vehicle

**FCAS** Frequency Control Ancillary Services

**GEMS** Greenhouse and Energy Minimum Standards

**GDP** Gross Domestic Product

**GJ** Gigajoule

**IEA**International Energy Agency

**ICEV** Internal combustion engine vehicle

**ISP** Integrated System Plan

**kW** Kilowatt

**kWh** Kilowatt-hour

**LED** Light-emitting diode

**LNG** Liquified natural gas

**LPG** Liquified petroleum gas

**MJ** Megajoule

**MW** Megawatt

**MWh** Megawatt-hour

**NatHERS** Nationwide House Energy Rating Scheme

**NEM** National Electricity Market (East Coast). The NEM refers both to the wholesale electricity market and interconnected electricity system serving the majority of customers in New South Wales, the ACT, Queensland, South Australia, Tasmania and Victoria. Western Australia is served by the Wholesale Electricity Market (WEM) and there are smaller grids in the Northern Territory and other parts of the country.

**NSP** Network Service Provider

**Energy Efficiency Council**

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