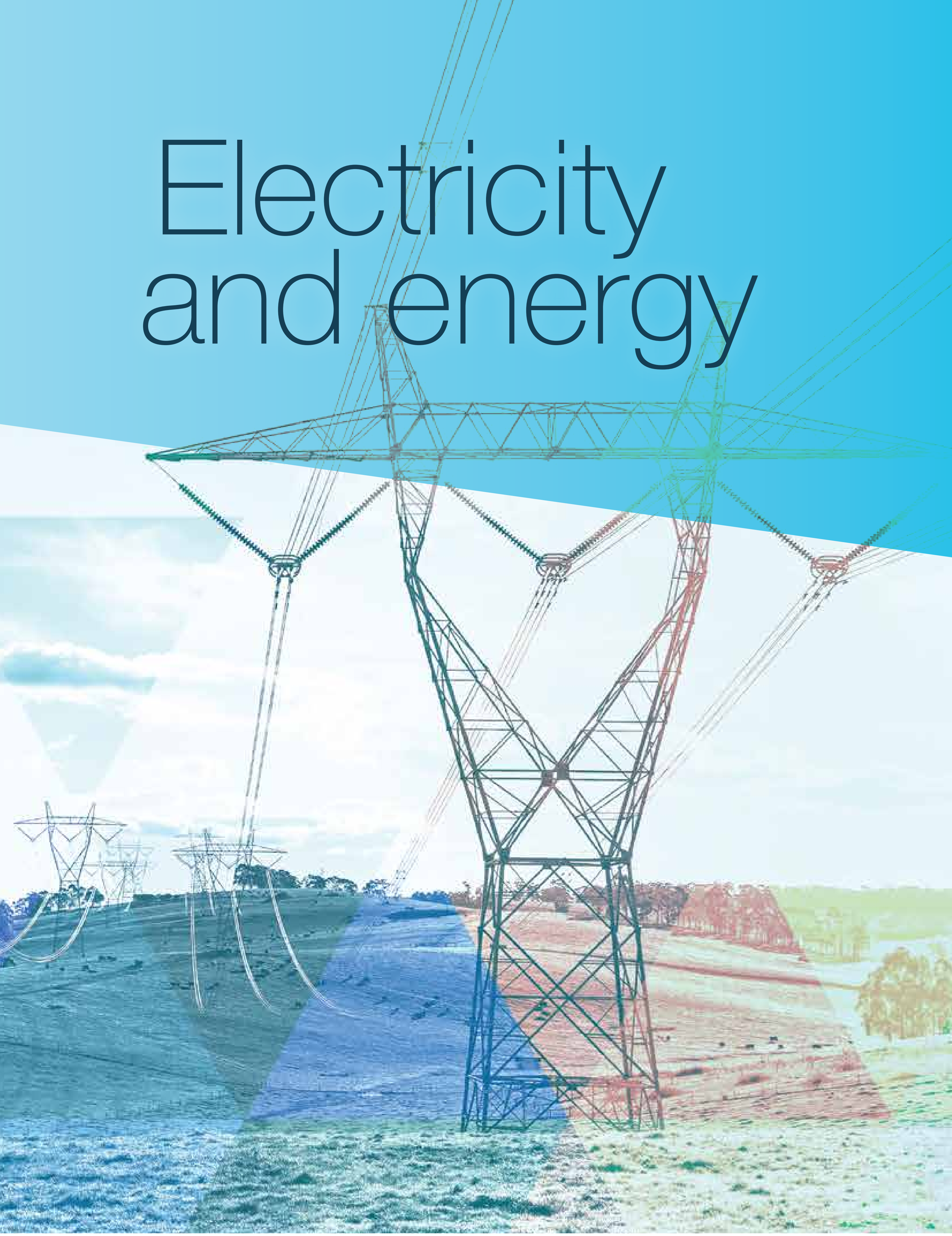
# Electricity and energy



ELECTRICITY AND ENERGY

# Sector summary

## Rapid decarbonisation and expansion of the electricity and energy sector is the key to meeting Australia's economy-wide emissions reduction targets. There is a clear and viable decarbonisation pathway for the sector that relies on known technologies to deliver very large emissions reductions and facilitate reductions in other sectors.

The electricity and energy sector accounts for 35% of Australia's emissions – higher than any other sector. Further, the decarbonisation of several other sectors (such as industry and transport) will not be possible without rapid transformation of the energy system. Energy loads in those sectors will need to be switched to electricity or derivatives of electricity, such as electrolytic hydrogen.

Renewable electricity generation and storage capacity must substantially increase through to 2050 if Australia is to meet its emissions reduction targets, and even more so if Australia is to contribute to global goals through clean energy intensive exports. The sector's decarbonisation technologies are well established: wind, solar PV, batteries, pumped hydro, with most of that generation capacity interconnected with transmission infrastructure. These technologies are commercial, but they will now need to be deployed at much greater scale. Uncertainty or delays in deployment will put emissions reduction ambitions at real risk.

The necessary infrastructure roll-out in this sector is complex, resource intensive and requires considerable planning and coordination. To ensure electricity is available when needed and is stored when demand is lower, firming and storage technologies that complement renewable generation must be deployed at pace and at scale. The reliability and security services provided by retiring coal-fired power generation must be replaced by new system security technologies, including some that have not yet been tested at grid-scale. Natural gas will be required for some time for firming and back-up supply. Additional transmission infrastructure will also need to be established to efficiently transmit electricity to distribution networks or storage.

There are persistent barriers to progressing this transformation at sufficient scale and pace. Global demand for transition materials will grow enormously over the long term, at times placing great pressure on supply chains. Government and industry must earn social licence from electricity consumers and from communities impacted by infrastructure. Planning and approvals processes must become better resourced, more efficient and transparent and strike an appropriate balance between climate and broader environmental objectives. Traditional Owners must be included as partners in the deployment of infrastructure on their land. The skilled clean energy workforce will need to grow substantially, and soon.

The sector's pathway requires government intervention to stimulate, broker and convene investment in technologies, update rules that govern Australia's energy markets, acquire social licence and support the stability of grids that will be under pressure from new demands.

## EE.1 Sector state of play

### EE.1.1 Economic contribution

In 2022-23, the electricity and energy directly added a gross value of $30 billion (rounded and based on current prices) to Australia's economy, which amounted to 1% of GDP. While this is only a small proportion of economic output, the essential services the sector provides support the operation of the entire economy. In 2022-23 the sector's workforce comprised 91,000 individuals, 24% of whom were female (Appendix B).

### EE.1.2 Sources of emissions

In 2022, the electricity and energy sector's emissions were 153.4 Mt $CO_2$-e or 35% of Australia's total emissions (Table EE.1) (CCA unpublished).

Electricity generation on Australia's grids contributes approximately 95% of the sector's emissions. Emissions from the manufacture and supply of energy products (e.g. the refining of petrol) is captured in the sector, noting the end use of these products mainly occurs in other sectors, such as transport. The sector will also include any emissions resulting from the production of hydrogen in the future, which is not currently mass-produced in Australia and for which such emissions are negligible.

The deployment of renewable energy generation and storage has driven emissions reductions in the electricity subsector. The emissions intensity of Australia's largest grid, the National Electricity Market (NEM), has reduced from 0.95 tonnes of carbon dioxide equivalent per megawatt hour ($CO_2$-e/MWh) in 2005 to 0.59 tonnes of $CO_2$-e/MWh in 2022 – a decline of 37% (Open NEM, 2024). This has been driven by the exit of coal-fired generation and growth in output from renewables, which increased from approximately 1,200 gigawatt hours (GWh) in 2005 to 81,000 GWh in 2023.

Table EE.1: Emissions sources in the electricity and energy sector

| Sub sector | Mt $CO_2$-e | Subsector share (%) |
|---|---|---|
| Electricity generation[1] | 145.9 | 95.1% |
| Petroleum refining | 2.4 | 1.6% |
| Other energy industries | 0.4 | 0.3% |
| Petroleum and coal product manufacturing | 1.3 | 0.9% |
| Military transport | 0.7 | 0.5% |
| Distribution of natural gas | 1.2 | 0.8% |
| Transmission of natural gas | 0.4 | 0.3% |
| Pipeline transport | 0.9 | 0.6% |
| Electrical equipment | 0.2 | 0.1% |
| Total | 153.4 | 100% |

Note: Mt $CO_2$-e and Subsector share (%) may not sum to the totals due to rounding.

1 Emissions associated with off-grid electricity are not captured in electricity generation. These emissions are captured in the Industry chapter

## Box EE.1: Achieving 82% renewable electricity generation by 2030

To continue supply of electricity while coal generators reach end-of-life and are withdrawn from the grid, Australia will need to rely on renewable electricity generation technologies such as wind and solar PV.

The Australian Government has a target of 82% renewable electricity by 2030. In 2023, in the electricity generation from renewables in the NEM averaged 39%. Rapidly increasing the share of renewables will provide a significant boost to the decarbonisation of the whole economy.

In its 2023 Annual Progress Report the authority raised concerns about progress to the 82% renewable electricity target and made a series of recommendations aimed at addressing delays. In the 9 months since, the government has taken important steps towards enhancing the prospects of achieving its target, including significantly expanding its Capacity Investment Scheme for encouraging new investment in renewable generation capacity and energy storage. As noted elsewhere in this chapter, there are still barriers to overcome.

The authority will update its assessment of progress to the 82% target in its 2024 Annual Progress Report.

## EE.2 Existing and prospective technologies

To identify the technology transition and emission pathways that best support Australia's transition to net zero emissions by 2050, the authority first applied criteria of cost competitiveness on a capital cost basis and prospective deployment timeframes. Other considerations, including abatement potential, barriers, finance, workforce matters, data gaps and the principles set out in the *Climate Change Authority Act 2011*, are discussed in later sections. Selected technologies are at Table EE.2.

Table EE.2: Technologies to support emissions reductions in the electricity and energy sector

| Emissions reduction opportunity | Deployment timeframe[2]<br>(Aurecon 2024) | Cost:[3]<br>BESS and PHES: $/KWh. All other rows: $/KW.<br>(Graham et al., 2024, except where noted) |
|---|---|---|
| Wind | Onshore<br>Development: 3 to 5 years<br>Construction: 2.5 years<br><br>Offshore<br>Development: over 7 years<br>Construction: 6 years | Onshore: $3,038<br>Offshore wind: $5,545 to $7,658 |
| Solar photovoltaic (PV) | Rooftop<br>2-3 days<br><br>Utility-scale<br>Development: 2 to 3 years<br>Construction: 1.5 years | Rooftop: $1,505<br>Utility-scale: $1,526 |
| Battery Energy Storage Systems (BESS) | Residential<br>90 days<br><br>Utility: 1-2 hr capacity<br>Development: 1-2 years<br>Construction: 1.5 to 2 years<br><br>Utility: 4-8 hr capacity<br>Development: 1-2 years<br>Construction: 2 years | Residential: $14,400 installed (Aurecon, 2024)<br><br>Utility: 1-2 hr capacity<br>1 hr: $1009; 2 hr: $731<br>Utility: 4-8 hr capacity<br>4 hr: $592; 8 hr: $519 |
| Pumped hydro energy storage (PHES) | Development: 3 to 5 years<br>Construction: 4 to 8 years | 6 hr: $635; 8 hr: $517<br>12 hr: $363<br>24 hr: $242 (mainland) - $150 (Tas)<br>48 hr: $142 (mainland) - $66 (Tas) |
| Gas Turbines | Development: 2 years<br>Construction: 2 years | Small turbine: $1,684<br>Large turbine: $1,059 |
| Hydrogen | Project contingent | Project contingent |
| Transmission | Project contingent | Project contingent |

With uptake of the technologies outlined in Table EE.2, the share of renewable electricity generation in the grid is projected to reach more than 99% by 2050, according to a number of modelling studies (Table EE.3). By 2035, these analyses project Australia's renewable share reaching between 81% to over 99%.

2 All year data are approximations rounded to the closest year or half year.
3 Figures are capital cost and are for 2023. The cost for Residential BESS is total cost.

Table EE.3: Share of renewable energy as primary generation

| Author | Scenario description | 2035 Renewable generation | 2050 Renewable generation |
|---|---|---|---|
| Net Zero Australia | Rapid electrification with full renewables rollout | 99.8% | 100% |
| AEMO | Green Energy Exports | 99.3% | 99.8% |
| Net Zero Australia | Rapid electrification | 98.8% | 99.6% |
| Climateworks | 1.5 degrees aligned | 98.2% | 99.8% |
| AEMO | Step Change | 95.6% | 98.6% |
| CSIRO for CCA | AusTIMES modelling (A40/G1.5) | 93.2% | 99.3% |
| Climateworks | well below 2 degrees aligned | 93.3% | 99.7% |
| CSIRO for CCA | AusTIMES modelling (A50/G2) | 89.5% | 98.8% |
| Net Zero Australia | Rapid electrification with constrained renewable roll-out | 88.3% | 99.2% |
| DCCEEW | Projections baseline | 83% | Not available |

*Sources: Calculated from (AEMO, 2024d; Climateworks Centre, 2023a; Davis et al., 2023; DCCEEW, 2023)*

Note: Climateworks figures included under 2035 are for 2036. AEMO ISP figures are for 2034-35.
Note: Net Zero Australia scenarios are domestic electricity generation only.

## EE.2.1 Wind

### EE.2.1.1 Onshore wind

Onshore wind power stations are a proven zero emissions source of electricity generation in Australia. The costs of installed wind generation are forecast to decline, however, limitations in global supply chains may mean these cost declines are not realised in the near term.

### EE.2.1.2 Offshore wind

The offshore wind industry in Australia's is still in its very early stages. The Australian Government has awarded feasibility licenses for six potential offshore wind projects off Gippsland's coast in Victoria, with a further six in Gippsland and one in the Hunter off NSW that are subject to consultation with First Nations communities. Further licensing will be required before construction and operation commence. Offshore wind is also the most expensive technology, by capital cost, in Table EE.2 and has a projected 10-year readiness timeframe.

Offshore wind resources can offer advantages over onshore wind, including stronger and less turbulent winds with generation profiles that are complementary to other technologies, such as solar PV. The location of offshore wind can negate some of the social licence impacts present with much of the sector's onshore infrastructure (Aurecon, 2024), including visual and noise pollution concerns. However, offshore wind also presents unique social licence challenges, including impacts on Sea Country for Traditional Owners (GLaWAC, 2022) and concerns over the impact of on-land infrastructure such as transmission lines necessary to connect offshore wind generation to the grid (AEIC, 2023).

## EE.2.2 Solar photovoltaic (PV)

### EE.2.2.1 Utility-scale solar PV

Utility-scale solar PV power stations are a proven zero emissions source of electricity generation in Australia.

### EE.2.2.2 Distributed solar PV

Mass deployment of distributed solar PV is a proven zero emissions source of electricity generation in Australia. Distributed solar provides system security benefits through reducing demand on the grid during the day. As more coordinated consumer energy resource battery systems are installed, rooftop solar could play a role smoothing demand outside daylight hours.

## EE.2.3 Energy storage

The Australian Energy Market Operator has forecast for the Optimal Development Path in its Step Change Scenario a quadrupling of firming capacity from sources alternative to coal that can respond to the changing output from variable renewable generation (AEMO, 2024a). Much of the forecast growth is in residential batteries (consumer energy resources forming 'virtual power plants'), which becomes increasingly important alongside utility-scale batteries and pumped hydro. The Australian Energy Council's submission (2024) stated that long duration storage requires policy support to provide certainty to investment decisions that factor in long build times, high capital expenditure and prospects of delay.

### EE.2.3.1 Battery energy storage systems (BESS)

AEMO's 2024 Integrated Systems Plan projects significant growth in residential batteries, to facilitate intra-day storage of rooftop solar during times of excess supply of electricity (AEMO, 2024a). Installed capacity of residential battery systems is projected to exceed total capacity of shallow (under 4 hours), medium (4 to 12 hours), and deep (12 hours plus) utility-scale BESS by 2035-36.

### EE.2.3.2 Pumped Hydro Energy Storage

Pumped hydro storage, capable of providing dispatchable generation more than 12 hours, can smooth out inter-day variations in demand and renewable supply in Australia's future high variable renewable energy grid. Pumped hydro is currently the most expensive form of available generation and storage on a capital cost basis and is a mature technology with limited expectations of deployment-driven cost reductions.

The Snowy 2.0 pumped hydro project is currently under construction with a forecast completion date of 2029 (AEMO, 2024a). There are a wide range of views on the benefits that this project may, or may not, deliver to electricity production and reliability in the NEM. Based on the current completion timeframe this project will come online when the NEM is reaching long run renewable energy generation of well above 50%, when the need for back-up and firming will be high.

## EE.2.4 Gas turbines

Open cycle gas turbines (OCGT) are currently a widely deployed technology in Australia and many modelling exercises see this role continuing through to 2050. As the Hunter Power Project in Kurri Kurri NSW has demonstrated, it takes considerable time to plan and deploy gas-fired generation. Forward planning is needed to identify whether, and if so how, the deployment of firming generation, including gas-fired power, is deployed in the system so that it is established at the required time and scale to enable the timely closure of coal power, without slowing deployment of renewables and storage.

To 2030, peaking infrastructure may be developed and operated as capable of running multiple fuels, such as natural gas and hydrogen (authority consultation with AEMO, 2024). While all new gas turbine projects could include provision for hydrogen blending and eventual conversion to hydrogen firing (AEMO, 2024a), 100% hydrogen gas turbines are not yet commercially available (Gilmore et al., 2023).

## EE.2.5 Hydrogen

There are two options available for the creation of zero emissions hydrogen as a fuel for electricity generation: electrolysis of water and stream methane reforming (SMR) of natural gas with CCS. Neither of these are in mass production in Australia in 2024.

Chevron Australia's submission (2024) suggested the use of hydrogen as a fuel for electricity generation can be pursued to lower the emissions intensity of dispatchable power, finding that the first uses of hydrogen for power generation will likely be in co-firing with natural gas. AEMO has assessed that hydrogen's ability to replace or blend with natural gas as a peaking fuel is constrained by the cost, as it is a relatively expensive fuel to produce at scale (AEMO, 2024a). The ISP notes the viability of green hydrogen as an alternative fuel to natural gas may increase if the cost-efficiency of hydrogen increases or there is greater government support for hydrogen turbines (AEMO, 2024a).

The Clean Energy Regulator (CER) and Department of Climate Change, Energy, the Environment and Water (DCCEEW) are developing a Guarantee of Origin (GO) Scheme to track emissions intensity for production of products (CER, 2024a). A GO Scheme is currently being developed for hydrogen (CER, 2024b).

## EE.2.6 Nuclear

Nuclear was not included in the authority's list of technologies to support emissions reductions in the electricity and energy sector (Table EE.2). The authority received seven submissions in response to its issues paper that discussed nuclear energy. The Minerals Council of Australia (2024) and the National Farmers' Federation (2024) both proposed that the existing legislative prohibitions on approval of nuclear power generation should be removed to facilitate its evaluation against other technology options. Five stakeholders provided submissions that stated that nuclear is not a technology solution for consideration due to its high cost and long lead times for deployment (EnergyAustralia, Farmers for Climate Action, IEEFA, Bushfire Survivors for Climate Action, Australian Conservation Foundation, submissions 2024).

Nuclear power generation is presently banned under federal legislation and there are also prohibitions at the state and territory level. The prospects for nuclear power stations in Australia are further diminished because of its high cost relative to other low carbon generation technologies. Australia's lack of experience in building and managing nuclear power stations may reasonably lead to additional costs for a first-of-a-kind unit deployed in Australia. The estimated lead time of 15 to 20 years before operation (Graham et al., 2024) suggests this technology cannot make a timely contribution to replacing the generation capacity of retiring coal-fired power stations or to helping Australia achieve its carbon budget targets to 2050.

Nonetheless, the size of Australia's decarbonisation tasks means where technologies are competitive and can make a material contribution to decarbonisation, they should be considered. For example, a future dramatic cost reduction in new build nuclear plants would necessitate a re-evaluation of this technology for deployment in Australia. In this context, nuclear should continue to be monitored as an option.

### EE.2.7. Transmission infrastructure

The NEM consists of approximately 40,000 km of transmission lines and cables. Achievement of AEMO's Optimal Development Path (ODP) as outlined in the 2024 ISP would require around 10,000 km of new transmission lines by 2050 (AEMO, 2024a). Additionally, West Australia's South West Interconnected System requires an additional 4,000 km in network augmentation to support an estimated 50 GW of new generation (WA Government, 2023b).

In addition to the large transmission growth needed to connect renewable energy zones and storage sites to demand centres, AEMO modelling has indicated the need for the construction of four interconnectors to transmit variable renewable electricity.

> Once investors have sufficient confidence that the transmission build-out is occurring, there can be efficiency gains from construction of generation infrastructure in parallel or near-parallel to the construction of transmission infrastructure.

## EE.3 Barriers, opportunities and enablers

### EE.3.1 Green premium

The authority's research found commercially mature technologies are struggling to move through the regulatory and policy environment, creating uncertainty for investors in Australia.

The Government's expanded Capacity Investment Scheme (CIS) is intended to deliver 32 gigawatts of renewable and clean dispatchable projects worth $67 billion, with the first tender process run in May 2024 (DCCEEW, 2024a). While stakeholders noted the size and scope of the CIS is sufficient for incentivising investment out to 2027, the authority notes that the design is unlikely to:

- attract tenders from long duration storage options such as pumped hydro storage, which will be necessary to balance the seasonal operation of the grid in the longer-term, but has lead times of over 8 years and relatively high upfront costs (CCA, 2022)
- support more nascent technology in the electricity and energy sector that may be needed longer term to reduce residual emissions in the sector
- provide the longer-term signals needed for investment in the sector beyond 2030.

The authority heard from stakeholders that public investment through grants, debt and equity options, is required to support private capital to varying degrees, depending on the level of maturity of a technology (IGCC submission, 2024). Some stakeholders noted equity investments in shared infrastructure of significant national value such as transmission and generation should be considered (Chevron Australia, Anonymous, submissions, 2024), while another noted long-term finance beyond 2030 is necessary to ensure a stable investment environment (Southerly Ten submission, 2024).

## Box EE.2: Producing and consuming more efficiently

Producing and consuming more efficiently can not only reduce emissions but also moderate the cost pressures on all six sectors as they decarbonise. This is particularly important to help minimise the build out of the electricity system required to support the substitution of clean electricity for fossil fuels. Enhancing efficiency also reduces costs for businesses and households and can provide health benefits (e.g. wellbeing effects from public and active transport, and thermal efficiency of housing) and environmental benefits (e.g. less waste).

There are many mature energy efficiency technologies. In the built environment, improvements to building thermal efficiency and appliance efficiency can reduce energy demand. Building energy demand can be further reduced by managing electricity loads through digitalisation and grid-integration of buildings. In the industry sector, energy efficiency can include process improvements and equipment upgrades, and technologies such as waste heat recovery.

The goal of a circular economy is to decouple economic growth from the negative impacts of resource depletion and environmental degradation (Hofmann, 2019). Transitioning to a circular economy has been receiving increased recognition for its potential to reduce emissions by decreasing material extraction, production, and transport (Bashmakov et al., 2023; Wang et al., 2022). A circular economy minimises waste, retains the value of materials, reduces the use of primary resources and keeps products, parts and materials circulating within supply chains (Morseletto, 2020). Examples include recycling organic material to recover nutrients, recycling ferrous scrap metal and batteries to reduce the need for ongoing resource extraction, and employing improved design to use less material in buildings.

On a pathway to net zero emissions, there will remain circumstances where fossil fuel use can facilitate a transition to zero emissions where lower emissions technologies are not yet available. In these cases, improving the efficiency of fossil fuel use may be the best way to reduce emissions. For example, gas will play an ongoing role in the electricity system as a firming technology to support an accelerated transition to renewables. Using lower emissions gas to replace metallurgical coal in steelmaking furnaces may be preferable if lower emissions technologies are not yet viable for a given facility. In some locations, continued use of gas as a feedstock in hydrogen production, particularly when combined with carbon capture and storage (blue hydrogen), may provide a low-cost source of hydrogen for decarbonising industries and smooth a transition to hydrogen produced with renewables and electrolysis (green hydrogen) as that industry develops.

### EE.3.2 Planning, approval and coordination

Several stakeholders have stated that a key barrier to deployment at the pace required are planning and approvals timeframes (Australian Energy Council, Stromlo Energy, Blue Carbon Lab, AGL, submissions 2024).

Approval timeframes can vary considerably between jurisdictions (CCA, 2023). Extended approval timeframes can be driven by factors including lengthy and inconsistent assessment processes involving multiple steps, poor coordination between agencies, frequent and unclear requests for information from agencies and approvals processes that are subject to changing expectations and implementation of new guidelines after applications have been lodged (HSF & CEIG, 2024).

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The process of seeking and obtaining approval to connect to the electricity grid may also be a barrier to investment in generation and storage capacity. The CEC raised concerns regarding uncertain timeframes, governance and the transparency of how decisions are made when generation applicants provide studies of expected plant performance (the 'R1' stage), finding these may cause investors to price in premiums associated with these risks, decrease or delay investment (CEC, 2023).

The Australian Government has options to expedite renewable projects. The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) approval processes could include processes to streamline applications and grant them a priority status (CCA, 2023). The Review of the EPBC Act found that 'improved community participation in processes can save time by ensuring that the right information surfaces at the right time and can be considered in the decision-making process.' (Samuel, 2020). Reform proposals for the EPBC regime include better community consultation, increased transparency and modernised regulatory practice, such as devoting more departmental resources to assist project proponents improve outcomes for the environment.

The CEIG recommends addressing planning and assessment bottlenecks under the EPBC regime and pointed towards its recent publications (HSF & CEIG, 2023, 2024) which identify a host of opportunities to speed up planning and approval processes at state levels. In New South Wales, these include using ministerial powers to declare any relevant categories of clean energy and transmission development to be considered Critical State Significant Infrastructure to enable an accelerated and streamlined approval process under the *Environmental Planning and Assessment Act 1979* (NSW).

The CEIG and Herbert Smith Freehills have also recommended the integration of renewable energy zones and strategic assessments with regional planning under the EPBC Act. This aligns with the Clean Energy Council's submission (2024) that timeframes and costs can be reduced by undertaking region-wide environmental and social assessments for renewable energy zones in place of a project-by-project basis. The Clean Energy Council further submitted that governments will need additional administrative capacity to expedite assessments; and that coordination within governments must be improved.

### EE.3.3 Supply chain constraints

Strong global competition for the components and materials of renewable energy generators poses a risk to the cost-effective and timely supply of electricity and energy infrastructure in Australia (AEMO, 2024a). Stakeholders have indicated to the authority that a whole-of-Commonwealth procurement strategy could avoid outcomes where Australian jurisdictions and project developers compete against each other for critical components and equipment which presents risks to project costs, viability, and timelines.

AEMO suggests that early investment in infrastructure to retain Australia's spot in the global supply chain queues and avoid out-year supply squeezes is an effective risk mitigation option (AEMO, 2024a).

An example of a supply chain risk is the availability of synchronous condensers and the time it take for these to be ordered and delivered. AEMO modelling has indicated that to maintain system strength in a NEM capable of sustaining 100% renewable penetration the equivalent of 40 synchronous condensers would be needed to provide inertia, frequency response, system strength and voltage control requirements (AEMO, 2022). The global market is highly competitive for large synchronous condensers, resulting in lead times in excess of five years to plan, order and deliver (AEMO, 2023).

### EE.3.4 Gaining social licence

Finding a suitable approach to engaging communities and landholders to earn trust and acceptance – social licence – is a key element for the successful roll-out of Australia's energy infrastructure (CCA Consultation 2024; AEMO, 2024a; Dyer, 2023).

The narrative regarding infrastructure's role in the energy transition, together with perceived benefits, are the two single most important factors in predicting social acceptance of living near renewable energy infrastructure (CSIRO, 2024a). Numerous stakeholders highlighted the importance of securing and maintaining social licence for enabling the buildout of energy infrastructure projects (Investor Group on Climate Change, Chevron Australia, Australian Conservation Foundation, Sydney Environment Institute, Griffith University, AGL, APA Group, Climate Integrity, submissions, 2024). However, the pathway for the electricity and energy sector is not well understood in Australia and people have relatively low levels of confidence on their knowledge of renewable energy infrastructure and its role in the transition (CSIRO, 2024a).

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The buildout of renewable energy generation, storage capacity and transmission infrastructure to support the achievement of Australia's emissions reduction targets will place significant pressure on impacted communities across Australia. Growing recognition across the Australian Government has driven seven different reform and consultation efforts dedicated to addressing this challenge (AEMO, 2024c), including the government's independent Community Engagement Review.

Stakeholders emphasised that putting a premium on benefit-sharing for host communities is key to removing social licence barriers. In consultation with the authority, RE-Alliance emphasised the importance of active community participation in the transition and the distribution of benefits. Next Economy submitted that communities have been asking proponents to approach community benefit sharing with the intention to meet genuine needs of the community and support development goals.

Next Economy submitted several examples of community benefit-sharing: creating shared value out of direct investments such as workers housing used for social housing after short-term use, developing new training facilities in the region, investing in local business and procurement, community funds, grants and scholarships, and landowner and neighbour payments. Offers of benefit-sharing that are not accompanied by sufficient community engagement risk being perceived by host communities as attempts to 'buy' social licence (CPA, 2023). Stakeholders have reflected this to the authority, finding that inability to access electricity from generation infrastructure can cause resentment among hosting communities.

Much of Australia's renewable energy infrastructure and energy supply chains will be located on land and sea to which First Nations have a legal right or interest[4] (AEMO, 2024b; CSIRO, 2024b). Engaging Traditional Owners as partners can reduce the material risk that unconstructive relationships create for projects and ensure that First Nations communities have opportunities to lead in Australia's clean energy transformation (ACSI, 2021; Evans & Polidano, 2022). Poor engagement can increase project costs, delay approval timelines and threaten project viability (Joint Standing Committee on Northern Australia, 2021).

As at July 2024, 16 Traditional Owner groups have partnered with proponents to lead or take equity stakes in renewable energy projects (FNCEN, 2024b). Barriers remain for such equitable partnerships to be widely

4 Collectively referred to as the 'First Nations Estate' or Australia's Indigenous land and forest estate

replicable across Australia, including exclusion from the finance system (ASIC, 2023; Evans & Polidano, 2022); inadequate public funding for representative body corporates (Woods et al., 2021); and absence of requirements for proponents to engage effectively through obtaining Free, Prior and Informed Consent (FPIC). Through its consultation processes, the authority heard that there is also a lack of access to capacity and capability development.

A small number of institutions that provide, or regulate, finance for the electricity and energy sector have committed to implementing FPIC as a condition of providing future finance or investment (ARENA, 2023; ASIC, 2023; ASFI, n.d.; Westpac, 2022). While the Clean Energy Council and KPMG (Clean Energy Council & KPMG, 2024) have released an industry-led guide for engaging with Australia's First Nations people on renewable energy projects, and First Nations organisations have published best practice guidelines (FNCEN, 2022), there is no whole-of-government led framework clarifying or requiring FPIC.

The First Nations Clean Energy Network submitted that energy systems planning should recognise First Nations rights, use and occupancy, and adopt an approach of early-stage and substantive engagement and participation in decision-making with First Nations communities (FNCEN, 2024a).

Through access to transparent, detailed and appropriate information about companies, projects and impacts, Traditional Owners can be empowered to guide the preparation, implementation, evaluation, and improvement of planning and approval schemes for the energy system.

### EE.3.5 Community-led information

The independent Community Engagement Review, the recommendations of which have been accepted by the Australian Government in principle (DCCEEW, 2024b), contains recommendations on improving complaints handling processes and communicating the impact of renewable energy infrastructure (Dyer, 2023). Recommendation six finds that the design of a communication program should include engagement with local stakeholders (Dyer, 2023).

RE-Alliance, in consultation with the authority, has suggested that an appropriate mechanism to address these recommendations is the presence of local community energy hubs, staffed by community members with strong expertise and local networks. Institutions to support ground-up representation of community interests are a key reccommendation of the Productivity Commission's Transitioning Regional Economies report (Productivity Commission, 2017). The Latrobe Valley Authority (LVA) and the Collie Delivery Unit (CDU) are two examples of transition institutions that have been established to coordinate or represent local community interests in regions impacted by energy infrastructure transitions. The LVA and CDU maintain local stakeholder working groups to guide implementation of transition plans (LVA, 2024; WA Government, 2020).

Anecdotal evidence from Australia (consultation with Macquarie University) supports overseas experience of certain co-benefits flowing from co-locating photovoltaics with grazing sites, reductions in livestock loss from extra shading, and increases in fruit size for certain crops. The shade provided by agrivoltaics can also provide benefits to agriculture through improved water retention and infiltration in soil, and improved microclimate and crop protection (CEC, 2019; Wydra et al., 2023). Uptake of agrivoltaics in Australia has been slow, despite proponents present in Australia, such as Iberdrola, engaging in the practice internationally (Iberdrola, 2023). A report into agrivoltaics in Australia found this has been driven by knowledge gaps, poor planning and a lack of clear policy guidance at the development stage (Stark & Bomm, 2023).

The Australian Government can stimulate the agrivoltaics industry through developing best practice guidance and decision-making frameworks. This would help alleviate risks of misaligned incentives between renewable energy proponents and pastoralists, such as minimum grass heights in grazing paddocks (Stark & Bomm, 2023).

### EE.3.6 Workforce shortages

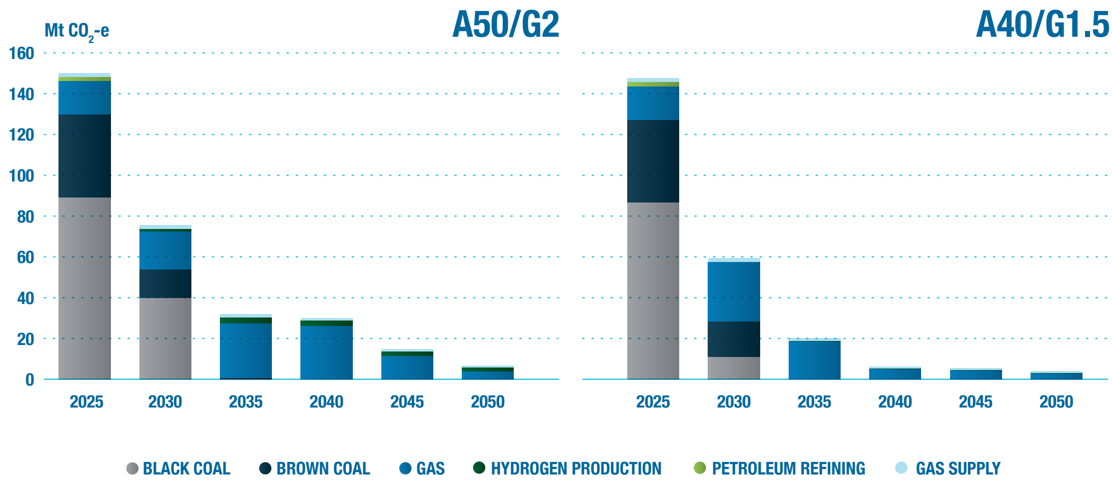
The electricity and energy sector requires a substantial increase of workers for the transition. Modelling undertaken for ARENA indicates that between 2025 and 2030 an estimated 10,400 electricians and 7,900 engineers will be required to roll out the sector's infrastructure (Accenture, 2023). Essential trades, such as electricians, and electrical and electronics engineers are both in a national (JSA, 2023a) and a global shortage (IEA, 2023), placing Australia in competition against international decarbonisation proponents.

The electricity and energy sector's labour demand also exists in competition with demand from other sectors for the same skills and occupations. This demand will exist in a highly competitive market, as sectors seek to decarbonise, often by investing in new technologies and electrifying operations (Climateworks Centre, 2023b). Jobs and Skills Australia's (2023b) modelling indicates that Australia will require close to two million workers in building and engineering trades by 2050.

## EE.4 Emissions pathways

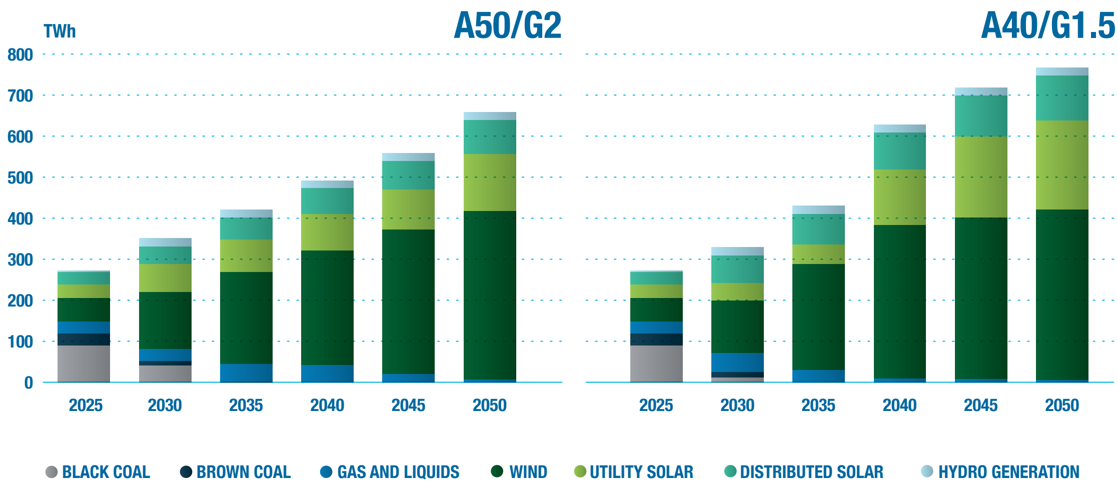
The results of the modelling undertaken for the authority by CSIRO and the authority's review of literature indicate that the electricity and energy sector is projected to undergo rapid decarbonisation over the period to the mid-2030s. The modelling results show emissions falling to approximately 32 Mt $CO_2$-e under A50/G2 and 20 Mt $CO_2$-e under A40/G1.5 in 2035 (Figure EE.1) driven by a significant build of renewable electricity generation (Figure EE.2).

Figure EE.1: Sector emissions by scenario




*Source: CSIRO modelling in AusTIMES commissioned by the Climate Change Authority.*
Note: Includes all electricity and energy sector emissions, including off-grid emissions, as per the description of the sector in this chapter.

Figure EE.2: Generation by technology and scenario




*Source: CSIRO modelling in AusTIMES commissioned by the Climate Change Authority*

## EE.4.1 Electricity generation

Total electricity generation per year, including electricity generated by pumped hydro and battery storage, is projected to increase significantly under both scenarios modelled by CSIRO. Under A50/G2, total electricity generation, excluding generation from pumped hydro storage and battery storage, is modelled to increase to 420 TWh in 2035 and 659 TWh in 2050 (Figure EE.2). Under A40/G1.5, generation is projected to increase to 431 TWh in 2035 and 767 TWh in 2050. CSIRO modelling forecasts that 37 TWh of this will be utilised to produce 0.8 Mt of hydrogen through electrolysis in 2035, and 119 TWh to produce 2.8 Mt of hydrogen 2050 under A50/G2. Under A40/G1.5, 42 TWh is forecast to be utilised to produce 1 Mt of hydrogen through electrolysis in 2035 and 155 TWh to produce 3.7 Mt of hydrogen in 2050.

## EE.4.2 Retirement of coal-fired power generation

Grid-connected coal-fired power generation capacity is projected to reduce from approximately 22 GW in 2025 to complete retirement by the mid-2030s under A40/G1.5 and under 0.1 GW remaining in A50/G2. Under its Optimal Development Path, AEMO expects that the remaining coal-fired power stations will retire two to three times faster than current scheduled announcements, with complete exit by 2036-37 (AEMO, 2024a). Such an outcome would be contingent on delivering replacement infrastructure at sufficient speed.

### EE.4.3 Reliability of supply

Both market forces and government policy are shaping the generation mix in Australia's major electricity grids. These factors are also supporting investments in firmed renewables, driving investments in grid supporting technologies such as gas-fired generation and pumped hydro, and there is state government policy to retain the reliability services of coal-fired generation.

State governments are taking decisions to support, in the short-term, the ongoing operation of coal-fired power stations. Their assessment has been that the reliability and security services provided by the coal-fired power stations in question are currently needed to secure the operation of the grid (AGL, 2024; NSW Government, 2024; WA Government, 2023a).

In submissions to the development of the Orderly Exit Management Framework, stakeholders report that interventions to extend the life of coal assets past their economic life risks creating policy uncertainty that distorts the investment climate for renewable deployment (Alinta Energy, 2024; CEC, 2024; IEEFA, 2024). The expanded Capacity Investment Scheme and state-government-led schemes that guarantee revenue floors for proponents may address some of this uncertainty. However, investors will require certainty beyond 2030, when the Capacity Investment Scheme and Renewable Energy Target are scheduled to end.

### EE.4.4 System security

The NEM is one of the first power systems of its size in the world to face the challenge of balancing high penetrations of renewable energy generation with maintaining system security (AEMO, 2024a). Currently, the synchronous generation of thermal plant provides many services to the grid that maintain system security, including voltage management, system strength, inertia, and frequency control. To successfully transition to net zero emissions these issues will need to be resolved in Australia. Modelling exercises, including that undertaken by AEMO for its integrated system plan indicate that these issues can be managed in the NEM. However, stakeholders are cautious about the ability of these outcomes to be delivered in practice.

It will be necessary to find ways to maintain sufficient system security services as thermal plants retire. The authority sought views from stakeholders on this issue including the Australian Energy Council (AEC). The AEC submission (2024) identified this issue as a gap in knowledge, suggesting that the path to maintaining essential system services for secure operation of the grid is not clear, and that these services must be deployed before synchronous generation provided by fossil fuel power generation can retire. In addition to providing fault current, synchronous generation provides inertia to grids that responds to initial changes in frequency and enable frequency control services to provide longer term system security.

As mentioned above, synchronous condensers can provide services currently supplied by fossil fuel generators. In the future, these services could also be provided by batteries. Tesla advised that utility scale battery systems with grid-forming inverters are being recognised for their ability to provide system security services. However, AEMO has noted that further testing is required to demonstrate utility scale battery systems can provide grid-forming services at scale in the absence of synchronous generation (AEMO, 2021). Addressing these issues will require action from market bodies, market participants, new investors, and jurisdictional bodies.

### EE.4.5 Peaking fuels

Peaking fuels are projected to play a firming role during times of peak demand on grids with high penetrations of renewable energy (AEMO, 2024a; Gilmore et al., 2023). If emissions-free gas alternatives such as green hydrogen gas turbines are not deployed, the deployment of gas turbines will result in residual emissions for the sector.

### EE.4.6 Residual emissions

Despite the availability of technologies to generate zero emissions electricity, many modelling exercises, including the modelling undertaken by CSIRO for the authority, find that there are likely to be residual emissions in this sector in 2050 (Table EE.4). This is because, based on current understanding, the operation of secure and reliable electricity grids will continue to require some use of fossil fuels mainly for the purpose of supporting the grid during periods of peak electricity demand.

Table EE.4: Residual emissions in 2050[5]

| Scenario | Emissions (Mt $CO_2$-e) in 2050 |
|---|---|
| A50/G2 | 7 |
| A40/G1.5 | 4 |
| Climateworks well below 2 | 1.2 |
| Climateworks 1.5 | 0.7 |
| 2024 ISP Step Change | 3.5 |
| 2024 ISP Green Energy Exports | 0.5 |

*Sources: Calculated from AEMO, (2024d); Climateworks Centre, (2023a).*

5 Emissions coverage varies between exercises, with the CSIRO modelling covering all domestic electricity generation plus energy supply, Climateworks covering all domestic electricity generation, and the ISP covering Australia's largest electricity grid, the NEM. Hence, figures are presented for illustrative comparison only.

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