Resilience of Origin's generation portfolio to a low-carbon economy

Scenario analysis under 2°C and 1.5°C warming pathways



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Important Notice

This report provides results of economic modelling on the potential impact to Origin's wholesale electricity generation portfolio under a number of emission reduction scenarios. These results do not represent an expected or preferred view of the future. As such, caution should be exercised when interpreting the results.

This report contains forward-looking statements, including statements of current intention, statements of opinion and predictions as to possible future events. Such statements are not statements of fact and there can be no certainty of outcome in relation to the matters to which the statements relate. These forward-looking statements involve known and unknown risks, uncertainties, assumptions and other important factors that could cause the actual outcomes to be materially different from the events or results expressed or implied by such statements. Those risks, uncertainties, assumptions and other important factors are not all within the control of Origin and cannot be predicted by Origin and include changes in circumstances, events or economic conditions that may cause objectives to change as well as risks, circumstances and events specific to the industry, countries and markets in which Origin operates.

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A message from the Chief Executive Officer



As one of Australia's largest energy companies serving more than four million customers, Origin has a responsibility to lead the effort to decarbonise the Australian economy and advocate on behalf of our customers for the policies and targets that achieve this.

Since we became the first energy company in the world to sign up to seven of the We Mean Business coalition commitments in 2015, Origin has continued to be a leader in lowering emissions. In 2017, Origin announced two targets to decarbonise our business. We are aiming to have 25 per cent of our generation capacity come from renewables and storage by 2020. We also set Australia's first independently approved science-based emissions targets of a 50 per cent reduction in Scope 1 and Scope 2 and a 25 per cent reduction in Scope 3 emissions, all by 2032.

We unequivocally support all the Paris Agreement and policies to guide a smooth transition to lower emissions without compromising on reliability and affordability. However, we believe Australia's Paris Agreement commitment to reduce emissions by 26-28 per cent on 2005 levels is not sufficiently ambitious to limit global warming to 1.5°C or less.

This paper sets out our second scenario analysis. It builds on our 2017 analysis and demonstrates how we have structured our generation portfolio to support both the transition to lower emissions and the resilience of our business in a low-carbon world. Here we set out what a 1.5°C goal may look like for Origin's generation portfolio.

While transitioning to a low-emissions future presents considerable challenges, we have positioned our energy portfolio to meet our targets. We will continue to review these targets while focusing on the key elements of affordability and reliability.

While the value of Eraring Power Station declines under both the 2°C and 1.5°C scenarios, it retains a net positive value due to its role in the transitional period as it will provide secure and affordable baseload power in the short- to medium-term. The value of Origin's portfolio is lower under a 1.5°C scenario compared to the 2°C case; however, it remains higher than under a low-action Nationally Determined Contributions (NDC) case.

Our role in limiting climate change, no matter how small on a global scale, presents us with a range of risks and opportunities. We have integrated climate change risk into our everyday decision-making process.

As we continue to bring more renewables into our generation mix, we know gas will play a vital role in ensuring the reliability of supply and bringing down emissions. Australia's energy market has long benefitted from our vast low-cost coal resources, but as we transition to a lower-emissions future, gas will play a pivotal role.

At the same time, we see digitisation and decentralisation as other significant shifts in the way energy is delivered to consumers. We have been actively trialling a range of different battery and demand-response technologies.

We are proud of the position we have taken and confident of the role we can play in getting energy right for our customers, communities and planet.



Frank Calabria
Chief Executive Officer

The global energy landscape

The Paris Agreement

The Paris Agreement is a landmark agreement, ratified by almost every nation, to combat climate change and accelerate and intensify the actions and investments needed for a sustainable low-carbon future. The agreement aims to strengthen the global response to the threat of climate change by keeping the global average temperature rise this century to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to less than 1.5°C.

IPCC Global Warming of 1.5°C report

On behalf of the signatory nations to the Paris Agreement, the United Nations Framework Convention on Climate Change (UNFCCC) invited the Intergovernmental Panel on Climate Change (IPCC) to produce a special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways (the *Global Warming of 1.5°C* report). In October 2018, the IPCC published the special report[1], with observed data showing human activities are estimated to have already caused approximately 1.0°C of global warming above pre-industrial levels. The report highlighted the urgent need for action at all levels – national, city, company and individual – to respond to the challenges ahead and strengthen action without delay. Some of the key messages from the *Global Warming of 1.5°C* report include:

- global annual emissions will need to be approximately halved by 2030, with no overshoot after 2050;
- the scale of the transition required to decarbonise is unprecedented;
- the risks associated with warming are substantially lower at 1.5°C than 2°C;
- global emissions will need to reach net-zero for all pathways by around 2050; and
- all pathways rely on carbon removal to some extent.

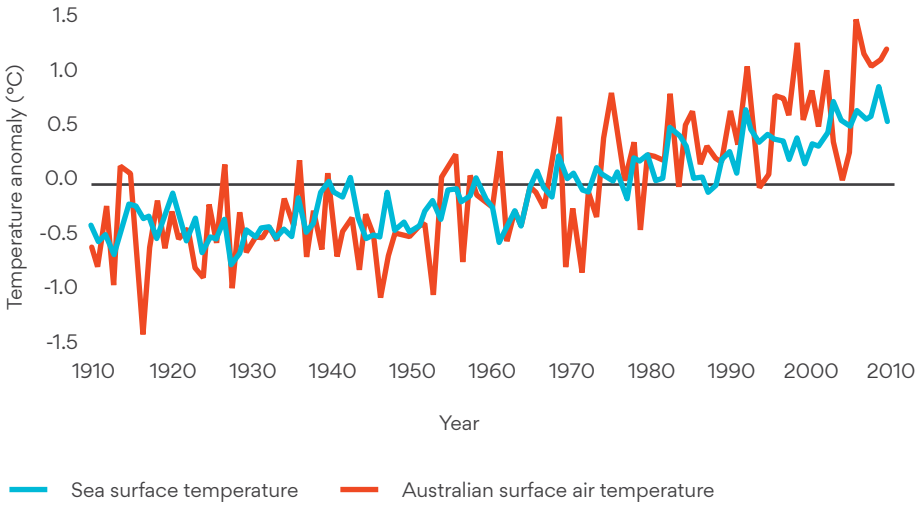
An Australian perspective

As one of Australia's leading energy companies, with more than 4 million customers, Origin is uniquely positioned to help lead the delivery of Australia's international emission reduction commitments.

As one of the driest continents on earth, Australia is especially vulnerable to further climate change. We are already experiencing the early consequences of climate change.

Australia's climate and ocean temperatures have warmed by around 1°C since 1910[2] and Australia's emissions are increasing. The effects of this increase are being seen in increased frequency of extreme heat events, more severe droughts, decreased rainfall, more extreme fire, weather and rising sea levels, all of which demonstrate Australia's vulnerability to further climate change impacts.

Average sea surface temperature anomolies



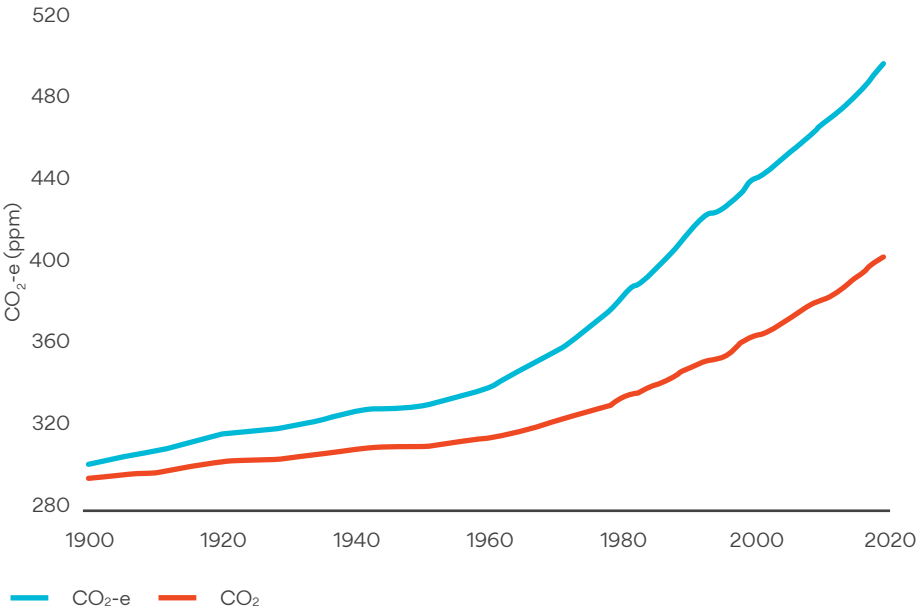
Time series of anomalies in sea surface temperature and temperature over land in the Australian region. Anomalies are the departures from the 1961-1990 average climatological period. Sea surface temperature values are provided for a boxed region around Australia (4–46ºS and 94–174ºE).
Source: State of the Climate, 2016. Bureau of Meteorology and CSIRO. [3]

1 ipcc.ch/sr15/.

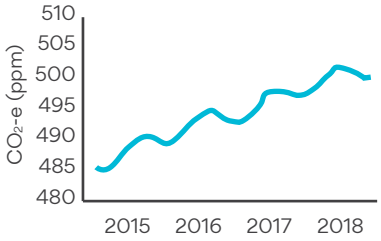
2 csiro.au/en/News/News-releases/2018/State-of-the-Climate-2018-Shows-Continued-Warming-of-Climate-and-Oceans.

3 climatechangeinaustralia.gov.au/en/climate-campus/australian-climate-change/australian-trends/.

Cape Grim-Antarctic carbon dioxide equivalent (CO_2-e) measurements[8]



Monthly mean CO_2-e measurements[8]



Calculated from the long-lived greenhouse gas radiative forcing data shown in the figure above, with CO_2 data shown on the left for reference. The annual data applies through to 2018. The inset panel shows the monthly mean CO_2-e data for Cape Grim from 2015 through to March 2019, showing CO_2-e surpassing 500ppm in July 2018.[7]

By monitoring the 'cleanest air in the world' at Cape Grim, Tasmania, Australia has been able to observe first-hand the fastest rate of change in rising CO_2-e concentrations than at any time in our history.

According to the Australian Government's Great Barrier Reef Marine Park Authority, "climate change is the greatest threat to the Great Barrier Reef and coral reefs worldwide".[4] The IPCC report advised that "coral reefs are projected to decline with losses (>99 per cent) at 2°C (very high confidence)". In 2016 and 2017, two consecutive years of marine heatwaves caused severe bleaching and coral loss along two-thirds of the Great Barrier Reef.[5]

Australia's unique flora and fauna is vulnerable to further climate change impacts, such as a recent Queensland heat event which resulted in an estimated 30 per cent loss of the spectacled flying fox population. The status of the species being updated to endangered. Australia also has what is thought to be the first recorded mammal extinction due to the effect of climate change, with the loss of the Bramble Cay mosaic-tailed rat (Melomys rubicola).[6]

At Origin, we understand our responsibility and are committed to playing our part, in limiting climate change, in line with the goals of the Paris Agreement.

4 gbrmpa.gov.au/our-work/threats-to-the-reef/climate-change.

5 nature.com/articles/s41558-018-0351-2.

6 environment.gov.au/biodiversity/threatened/species/pubs/64477-listing-advice-22022019.pdf.

7 blog.csiro.au/more-greenhouse-gas-in-atmosphere-than-you-may-have-realised/.

8 csiro.au/en/Research/OandA/Areas/Assessing-our-climate/Greenhouse-gas-data.

Origin's position on climate change

- We unequivocally support the Paris Agreement and measures to progressively reduce global emissions.
- We view Australia's current 2030 emissions reduction target as a starting point but not sufficiently ambitious for a 1.5°C goal.
- We believe the electricity sector needs to deliver more than its proportional share to enable the economy to transition to a low-carbon future.
- We see the transition to a low-emissions energy sector as a key strategic priority for Origin.

We have advocated for clear government policies to achieve Australia's 2030 emissions reduction target and a goal of net-zero emissions for the electricity sector by 2050. We support and continue to advocate for a long-term policy to achieve the objectives of ensuring security and affordability, and facilitating the transition to a modern, cleaner energy future.

At a time when the price and reliability of Australia's energy has been questioned, we are mindful of the significant challenge of balancing the transition to a low-carbon future, with a secure and affordable energy supply. We believe a stable long-term policy would provide the optimal solution for Australian homes and businesses. We will continue to advocate for this on behalf of our customers.

Origin has structured its generation portfolio to grow and prosper in a carbon-constrained world. We believe that the transition to a low-carbon future presents Origin with opportunities to create value, given the resilience of our existing operations and a strategy focused on growth in renewables, flexibility in gas and storage (both hydro and battery), and delivering cleaner, smarter energy solutions to customers.

Our commitments

In 2015, Origin became the first energy company in the world to commit to the first seven **'We Mean Business'** coalition commitments, including setting ourselves the goal of achieving an independently endorsed science-based emissions reduction target.

In 2017, we committed to significantly grow our renewable generation. We have a target that renewable generation and storage will make up more than 25 per cent of our total owned and contracted generation capacity by 2020.

In 2017, we published our first climate scenario modelling analysis, examining our wholesale generation portfolio resilience under three scenarios: business-as-usual (BAU), Australia's NDC of a 26-28 per cent decrease in absolute emissions from 2005 levels and a 2°C scenario, aligning with the Paris Agreement.

In late 2017, we became the first Australian company to have a Paris aligned emissions reduction target approved by the Science Based Targets initiative (SBTi). The SBTi is an independent body made up of representatives from the World Resources Institute, the Carbon Disclosure Project (CDP), the World Wildlife Fund (WWF) and the UN Global Compact.

Our emissions reduction target is:

- a 50 per cent reduction in our absolute Scope 1 and Scope 2[9] emissions by 2032, from our 2017 base year; and
- a 25 per cent reduction in our absolute Scope 3[10] emissions by 2032, from our 2017 base year.

In this paper, we extend our climate scenario analysis work by publishing our first 1.5°C portfolio resilience paper.

At Origin, we understand the challenges we face in transitioning to a low-emissions future. We have long positioned our portfolio in anticipation of delivering on that challenge. We are proud of our targets and will continue to review all targets in-line with the latest climate science throughout the transition period. Our Board, management and employees recognise the responsibility of our company to show leadership in addressing the challenge of climate change, while improving affordability and ensuring system reliability for our customers, and we hope to successfully meet the challenge.

[9] Scope 1 emissions are from sources that are owned or operated by Origin, in particular electricity generation and gas development. Scope 2 emissions result from the electricity that we consume to power our offices and operating sites.

[10] Scope 3 encompasses indirect emissions, other than Scope 2, relating to our value chain that we do not own or control, including wholesale purchases of electricity from the NEM. A SBTi approved Scope 3 target must cover at least two-thirds of total Scope 3 emissions. Our Scope 3 target excludes emissions associated with LPG, Corporate and Australia Pacific LNG export volumes, as these emissions constitute less than one-third of our total Scope 3 emissions.

Our framework

Our five pillars of decarbonisation

1
Exit coal-fired generation by 2032.

2
Significantly grow renewables in our portfolio.

3
Utilise our strong gas position as a lower-emissions firming fuel.

4
Empower customers with cleaner, smarter energy solutions.

5
Demonstrate leadership in climate change advocacy.

Our targets are underpinned by our five pillar approach to progressively drive the decarbonisation of our business. See Origin's 2019 Sustainability Report for more details about the five pillars at originenergy.com.au/sustainability.

Our strategy

At Origin we have a long history of investing in low-emissions technology that will change the way we think about energy. Since 2000, we have invested more than $800 million in renewable technologies and development options, including solar, geothermal and hydro. We have also invested another $50 million in data analytics and digital technologies, aiming to provide convenient, seamless and secure energy solutions of the future for our customers. Our focus is on developing technologies to connect customers to cleaner, smarter energy solutions. We are excited by the challenges and prospects ahead as we move to a more decentralised and digitised energy world.

Integrating climate risk into everyday decision-making

Origin continues to ensure climate change risks and opportunities are integrated into our core business strategy and portfolio decisions. Our models, including this analysis, are used as an input into the evaluation of future investment and portfolio strategy decision-making. We also incorporate a range of carbon prices into our annual strategic financial planning process.

Climate-related risks are identified and assessed in accordance with Origin's defined risk management requirements and are core considerations of our strategy and risk management process.

Climate change scenario analysis plays a significant role in our assessment of the assets we should hold, invest in, dispose of and acquire. This analysis is conducted as part of the annual strategic planning process that tests the resilience of our portfolio and investment decisions against a range of outcomes. All major Origin capital expenditure and investment decisions are subject to a formal Review & Approval process which is overseen by the Origin Investment Committee (OIC). The OIC is comprised of Origin's executive leadership team, which assesses material capital projects against a range of climate-related scenarios.

Growth in renewables

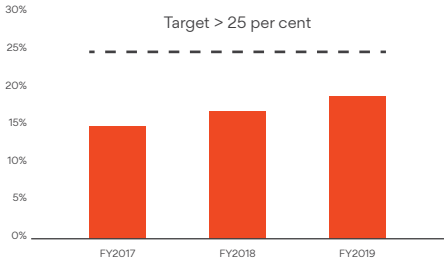
Renewable energy is the lowest cost generation investment option in Australia today. Fuelled by our country's vast solar, wind and hydro resources, we expect the majority of future investments in power generation will be renewable energy, firmed with natural gas and storage in the medium- to longer-term.

Since 2017, when we released our 2°C resilience paper, there has been some 5.7 GW of renewable capacity installed in the National Electricity Market (NEM), representing more than 10 per cent of total installed capacity in the NEM, and there is a further 5.3 GW committed for construction in the next two years.

There are many more gigawatts of capacity in the planning phase under consideration.

By 2020, we are targeting renewables and storage to make up more than 25 per cent of our owned and contracted generation capacity, compared to 19 per cent today and 15 per cent at the time of our 2°C resilience paper in 2017. Beyond 2020, we expect renewables will continue to play a key role in achieving our decarbonisation strategy and meeting our emission reduction targets.

Origin's owned and contracted renewables and storage capacity as a percentage of total generation capacity.



Of major economies, Australia has the largest uptake of household solar installations and capacity per capita.[11] Origin is the leading installer of commercial solar systems in Australia and ranked second in terms of overall installed capacity. In residential solar installation, we consistently occupy a top three position and continue to explore improvements in our product portfolio and customer engagement activities to grow our position.

The role of gas in the transition

One of the questions we are often asked by our stakeholders – customers, investors, employees and the community at large – is **how will gas play a role in the transition to a low emissions future and for how long?**

In answering these questions, our thinking is guided by science and our actions are driven by our desire to produce solutions that deliver lower emissions for all our customers. We believe natural gas has an important role to play in supporting emission reduction efforts in Australia and throughout the Asia-Pacific region.

"No single mitigation option in the energy supply sector will be sufficient to hold the increase in global average temperature change below 2°C above pre-industrial levels."

IPCC, Climate Change 2014, Mitigation of Climate Change, WG III, 5th Assessment Report

In its 5th Assessment Report, the IPCC highlighted one of the main mitigation options in the energy supply sector to be **"switching from (unabated) fossil fuels with high specific GHG emissions (e.g. coal) to those with lower ones (e.g. natural gas)".**

Accelerated electrification of energy end use, coupled with the decarbonisation of the majority of electricity generation, has been modelled by the IPCC as meeting the Paris Agreement's emissions objectives. Scenarios that achieve decarbonisation of the transport sector do so by taking advantage of a largely decarbonised electricity sector.

"The two roles for gas-fired generation - natural gas offers two benefits in the 2°C scenario:

i) per unit of electricity generated, it has half the CO_2 emissions of coal; and

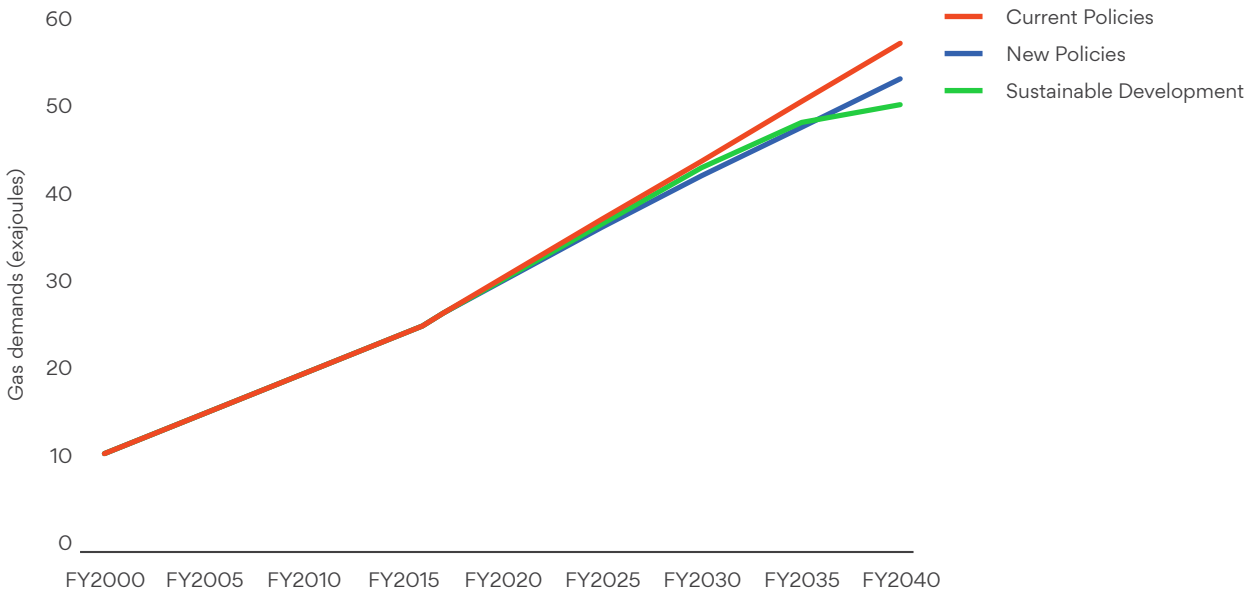
ii) gas-fired generation technologies can support the integration of VRE."[12]

IEA, Energy Technology Perspectives 2014

The IEA's 2018 World Energy Outlook presents three pathways for global energy sector development: Current Policies, New Policies, and the Sustainable Development Scenario (B2DS), which is aligned with the more ambitious Paris Agreement commitments, limiting future temperature increases to 1.75°C.

Under all three pathways, gas demand in the Asia-Pacific region is forecast to grow until at least 2040, reflecting the substantial variation in decarbonisation pathways across different regions and the very different role gas will play in different countries as their energy sectors transition.

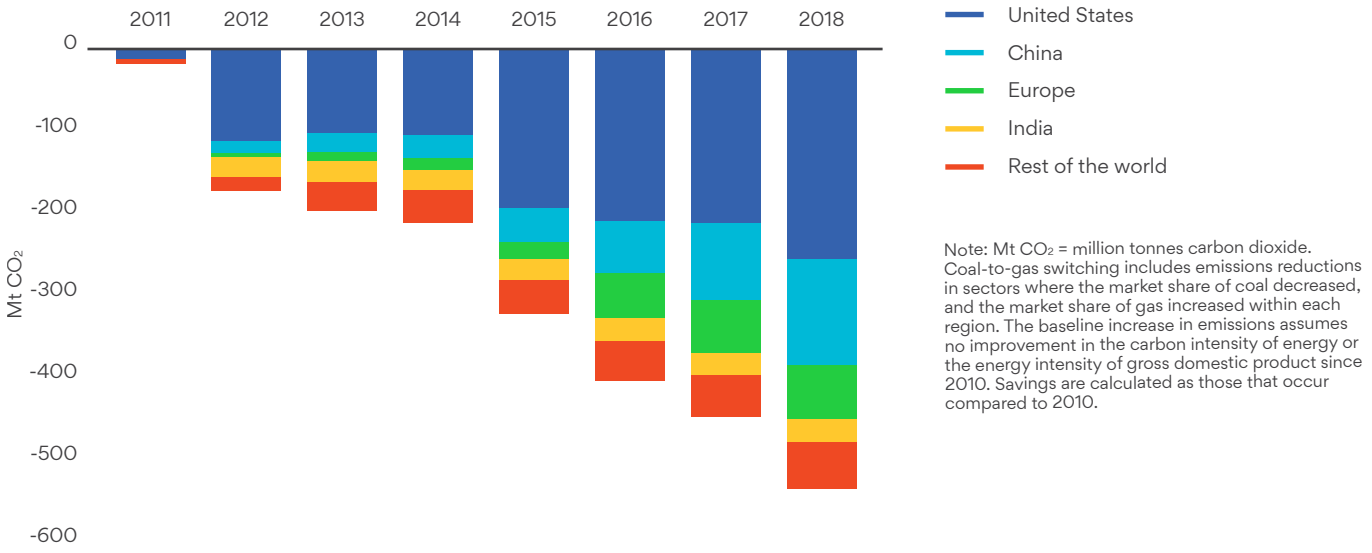
Asia-Pacific Gas Demand - International Energy Agency (IEA), 2018 World Energy Outlook



[11] cleanenergyregulator.gov.au/Infohub/Media-Centre/Pages/Media%20updates/NewsItem.aspx?ListId=19b4efbb-6f5d-4637-94c4-121c1f96fcfe&ItemId=589.

[12] Variable renewable energy.

CO_2 savings from coal-to-gas switching by region compared with 2010[13]



Note: Mt CO_2 = million tonnes carbon dioxide. Coal-to-gas switching includes emissions reductions in sectors where the market share of coal decreased, and the market share of gas increased within each region. The baseline increase in emissions assumes no improvement in the carbon intensity of energy or the energy intensity of gross domestic product since 2010. Savings are calculated as those that occur compared to 2010.

Origin's Integrated Gas business includes 37.5 per cent ownership and upstream operatorship of Australia Pacific LNG (APLNG). APLNG sells gas to customers in China, Japan, Australia and throughout the Asia-Pacific region.

Coal-to-gas switching in APLNG's customers' markets, such as China, has played an important role in helping to limit the growth in CO_2 emissions while also contributing to improving air quality.[13]

Coal-to-gas switching has helped prevent faster growth in emissions since 2010

Australia's electricity market, like many of our neighbours in the Asian region, has benefited from our vast low-cost coal resources to supply our electricity. The challenge facing Australia is how we replace the electricity generated from our coal-fired power stations.

In FY2019, coal-fired generation supplied 74 per cent of the electricity generated in the NEM with very little change over the previous five years. Continuing at this level is unsustainable; however, replacing Australia's coal fleet with renewable generation backed by battery and hydro storage in the near term is currently uneconomic. If we are to meet the urgent challenge of low emissions energy and ensure reliable capacity in a cost-effective manner, then gas can and will play a key role in the transition.

With renewable energy now Australia's lowest cost generation investment, gas can play a crucial role in integrating intermittent renewable technologies into the grid. Gas-fired generation can react quickly to peaks and troughs in demand, as well as intermittent renewable supply.

Origin owns Australia's largest fleet of gas-fired peaking power stations. We currently have 500 MW of generation capacity, which can respond in 10 minutes to ramp up requirements (1,000 MW in 15 minutes). We regularly review market requirements to assess the viability of upgrades to our remaining fleet. The duration of firming required will vary hourly, daily, weekly and seasonally, and our modelling shows that both gas and storage can play a key role in managing these fluctuations.

[13] IEA, 2019, The Role of Gas in Today's Energy Transitions https://www.iea.org/publications/roleofgas/.

Minimising fugitive emissions

IPCC modelling tells us that, to be effective, **"the fugitive emissions associated with natural gas extraction and supply are low or mitigated".**

Origin recognises that in order to maximise the climate benefits of natural gas, minimising emissions, particularly methane emissions, is essential. This is a key focus for Origin, which is evidenced by our methane emissions from venting and leaks from infrastructure remaining at approximately 0.1 per cent of metered sales gas from operated areas.

Embracing a decentralised and digitised future

Energy markets around the world are rapidly transforming and Australia is no exception. The continued penetration of distributed assets, combined with the rise of internet-enabled devices, are changing the way our customers use energy and the way energy will flow and be balanced in the future. Origin believes significant opportunity exists in the transformative impact of decarbonisation, decentralisation and digitisation on the energy sector, and our strategy positions us to be at the forefront of this transition.

We have been actively trialling a range of battery and demand-response technologies and testing these in a virtual power plant trial. The development of a virtual power plant brings together several initiatives Origin has been trialling to help customers embrace the benefits of decarbonised and decentralised energy.

We have trialled an internally developed artificial intelligence (AI) platform to connect and orchestrate distributed assets. We have run demand response events and are now planning several other customer trials to extend the AI platform capability. Ultimately, the platform will be used to deploy a variety of customer solutions and will be instrumental in managing distributed assets at critical times of market volatility.

In the past three years, Origin has reviewed in excess of 2,000 energy start-up companies through our international innovation ecosystem. We have scouted, evaluated, trialled, partnered with and invested in a number of technologies and solutions across a range of areas we believe will be integral to the energy solutions company of the future. The digitisation and deployment of smart grid technologies and flexibility to integrate increasing renewable energy will be key to the future of the energy sector. Our key innovation initiatives include:

- We co-founded FreeElectrons, a global accelerator program that brings together forward-thinking utilities and leading start-ups in the areas of renewables, smart grids, electric vehicles and home energy management.
- We are the principal sponsor of EnergyLab, the University of Technology Sydney's hub for clean energy innovation.
- We have established a presence in California's Silicon Valley to better connect Origin to the global epicentre of digital innovation.

We will continue to invest in research and development, bring innovative products to market and support this with a program of digitisation to ensure we continue to improve how we serve our customers. And we will continue to look for new ways to empower customers with cleaner, smarter energy solutions.

Emissions reduction scenarios

Our Energy Markets business accounted for 93 per cent of our Scope 1 and 89 per cent of our Scope 1 and Scope 2 emissions in FY2019.

Our Integrated Gas business, through the 37.5 per cent ownership of APLNG, plays a role in supporting emissions reduction efforts in Australia and throughout the Asia-Pacific region through the sale of natural gas. A significant proportion of the valuation of our Integrated Gas business is driven by oil and gas prices, which contain a significant degree of uncertainty under both the 2°C and 1.5°C scenarios. At 30 June 2019, a US$1/bbl movement in the long-term oil price would have had an impact of approximately +/- US$390 million on the valuation of APLNG.[14]

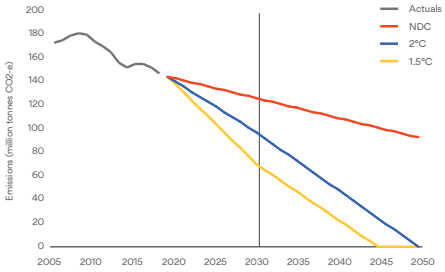
Given the weighting of emissions from the Energy Markets business and the fact we have separately disclosed the sensitivity to oil price (above) in Integrated Gas, it is appropriate to continue to focus emission reduction scenario analysis on the impact to Origin's wholesale electricity generation portfolio.

Emissions targets for the electricity sector

Three scenarios are presented that identify different energy technology solutions and policy pathways. The three potential pathways are primarily driven by emissions reduction targets for Scope 1 electricity emissions in the NEM through from 2030 through to 2050.

The *Global Warming of 1.5°C* report highlights that global emissions will need to reach net-zero for all pathways by 2050. Our 1.5°C scenario reaches net-zero emissions in the electricity sector in 2045, highlighting the leading role that is required from the sector if our economy is to transition rapidly.

Origin National Electricity Market Greenhouse Gas Emissions Scenario Pathways



Scenario 1: Nationally Determined Contribution (NDC)	• Electricity emissions reductions are in line with Australia's Paris NDC commitment to reduce absolute emissions by 26–28 per cent from 2005 levels by 2030. The emissions profile to 2040 assumes a continuation of the same rate of abatement resulting in global warming of ~3°C.[15]
Scenario 2: 2°C Pathway (2°C)	• The electricity emissions reduction trajectory is consistent with the Paris Agreement goal to hold the rise in global temperatures to below 2°C, effectively decarbonising the electricity sector by 2050 In 2030, this would be equivalent to a 45 per cent reduction on 2005 levels, in line with the lower end of the range proposed by the CCA[16], with a pro-rata target for the electricity sector.
Scenario 3: 1.5°C Pathway (1.5°C)	• The electricity emissions reduction trajectory is consistent with the Paris Agreement to hold the rise in global temperature rise to a 50 per cent chance of below 1.5°C, decarbonising the electricity sector well before 2050. In 2030, this would be equivalent to a 60 per cent reduction on 2005 levels, in line with the high end of the range proposed by the CCA, with a pro-rata target for the electricity sector.[17]

14 Further breakeven oil-price guidance is provided in the Operating & Financial Review in Origin's half-year and full-year reporting.

15 In our 2017 climate scenario modelling analysis we also included a BAU pathway. This scenario has been excluded from this report as the influx of renewable generation capacity under the LRET, in conjunction with state-based renewable targets, energy-efficiency schemes and continued growth of behind-the-meter solar photovoltaic are projected to deliver electricity emissions in line with the NDC scenario. We note that the electricity sector alone meeting its share of an NDC target is insufficient for Australia to meet our Paris commitments. United Nations Environment Programme, (2018), Emissions Gap Report. wedocs.unep.org/bitstream/handle/20.500.11822/26879/EGR2018_ESEN.pdf?sequence=10.

16 climatechangeauthority.gov.au/.

17 Origin notes the recent Independent Expert Panel Review on Interim Emissions Reduction Targets for Victoria (2021–2030) concluded the 60 per cent CCA target is closer to a 90 per cent likelihood of below 2°C. However, in conjunction with our view that the electricity sector should deliver more than its proportional share, we believe this target is consistent with our 1.5°C electricity scenario modelling. climatechange.vic.gov.au/__data/assets/pdf_file/0016/420370/Final-Report_Interim-Emissions-Reduction-Targets.pdf.

Modelling approach

To achieve any of the required targets, all our emission reduction scenarios require a carbon price for the electricity sector. Our modelling assumes a closed-system Baseline and Credit scheme – a form of emissions trading scheme that operates by setting an annual carbon intensity target for the market, which declines at a rate consistent with meeting the relevant 2030 or 2050 emissions reduction goal.

Under this approach, an individual generator either pays or receives a carbon credit at a rate equal to the difference between its carbon intensity and the target market carbon intensity for each unit of energy it generates. The modelling used a closed-system within the electricity sector, which is primarily required due to the long-term nature of investments associated with electricity generation and storage. The scheme delivers the long-term confidence and policy stability required to underpin significant capital investments during the transition to a low-emissions future. The carbon cost/credit of generation is incorporated into a generator's marginal cost and therefore its bidding and dispatch behaviour. The mechanism is predominantly self-funding as credits for lower emissions generation are funded from higher emissions generation. As a result, much of the cost is internalised within the wholesale electricity market.

Origin supports a carbon price market mechanism as it would facilitate achieving the least cost abatement outcome overall, and our modelling shows this to be the most effective way to achieve that goal.

The impact of the emissions reduction scenarios have been modelled using third-party market software, PLEXOS, which simulates expected half-hourly electricity dispatch volumes and pricing across the NEM. The modelling incorporates known constraints, such as operational limitations of coal and gas generation, including minimum generation levels, inter-regional transmission constraints and operational constraints for other plant, including hydro and battery storage.

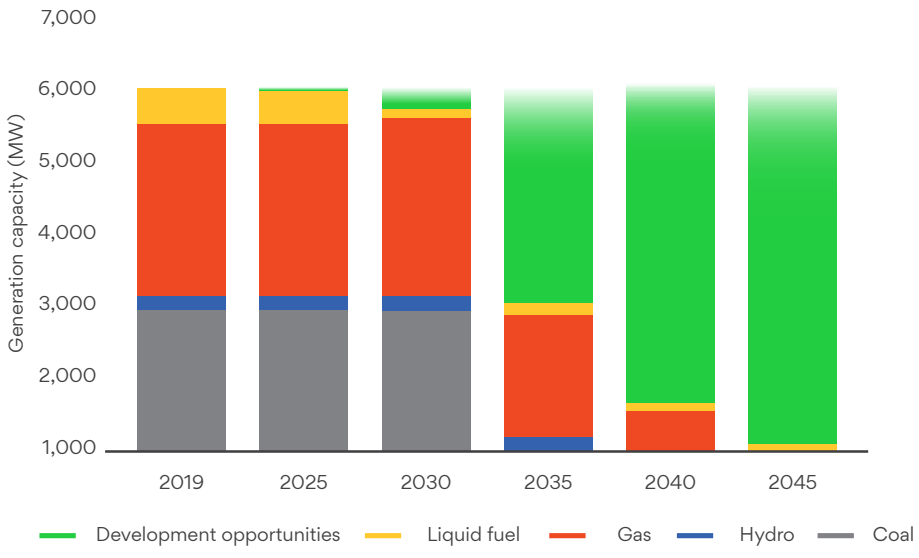
Generation dispatch and pricing outputs from PLEXOS were then fed into an in-house financial model to assess the valuation impact on Origin's wholesale electricity generation portfolio.

Key modelling assumptions

Timeframe

While our emissions scenarios run until 2050, our detailed half-hourly electricity market modelling focussed on the 2020 to 2040 primary transition period. All our portfolio asset valuations end at the technical end of asset life, the majority of which are prior to 2040.

Origin Generation Portfolio - Asset Life



Carbon pricing

All scenarios require a carbon price to meet the targets. Many economists have been advocating this for years[18,19,20] and it was again highlighted by a recent letter by 45 prominent economists submitted to the *Wall Street Journal*[21]. A carbon price offers the most cost-effective lever to reduce carbon emissions at the scale and speed that is necessary, this is why Origin continues to support a carbon price market mechanism.

It is assumed the market will adopt a carbon price from 2023 for the 2°C and 1.5°C scenarios. The NDC scenario requires a carbon price from 2031 to sustain the required emissions reduction trajectory. The carbon price represents the price required to sufficiently alter the bid-stack to achieve abatement outcomes. Being a baseline and credit scheme, the carbon price is passed through to different generators at different rates based on their carbon intensity.

Prior to the scheme commencing, renewables will receive the value associated with large-scale renewable energy target (LRET) certificates, as currently occurs.

Under each scenario, Origin's existing contracted renewables portfolio is valued by comparing the bundled cost of Origin's Power Purchase Agreements (PPAs) against the modelled outlook for electricity spot and LRET or carbon market prices.

Fuel costs

Generator fuel costs are modelled internally. They represent a blended mix of estimated contracted and uncontracted pricing (for both gas and coal), plus transport costs to the individual generator.

Generator new build and retirement

The retirement of plants and introduction of new plants are dictated by economic outcomes and subject to system reliability requirements. Supply is maintained to meet maximum demand plus a minimum reserve requirement in each state.

Generators are retired based on announced retirement dates or when fuel plus fixed costs are not being covered over an extended period.

Retired generation is replaced with the most cost-effective source of energy and capacity given the proposed life of the plant from the time it is built. This can be one or a combination of firm capacity and renewables, depending on prevailing and forecast market conditions.

The modelling approach takes into account generation plants' short-run marginal cost (SRMC) plus a premium to cover overhead costs.

Demand and distributed generation

We model national electricity demand scenarios that include estimates of behind-the-meter solar photovoltaic (PV) systems, and battery uptake and improvements in energy efficiency across the residential, commercial and industrial sectors. Solar PV and battery uptake increases with the abatement targets under the assumption that incentives will be aligned with wholesale policy.

Electric vehicle uptake is also included, with uptake rates consistent with CSIRO estimates.[22]

18 oecd.org/env/tools-evaluation/effective-carbon-prices-9789264196964-en.htm.

19 pc.gov.au/inquiries/completed/productivity-review/report/5-improving-markets.

20 pc.gov.au/inquiries/completed/carbon-prices/report.

21 clcouncil.org/economists-statement/.

22 aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/NEM_ESOO/2018/Projections-for-Small-Scale-Embedded-Technologies-Report-by-CSIRO.pdf.

Scenario analysis results

Summary table

	2030				2040			
	Abatement (% of 2005)	Renewables share (TWh%)	Behind-the-meter PV (TWh)	Coal retirements (GW)	Abatement (% of 2005)	Renewables share (TWh%)	Behind-the-meter PV (TWh)	Coal retirements (GW)
NDC	28%	41%	25	4	36%	50%	37	8
2°C	45%	49%	31	6	72%	70%	47	17
1.5°C	60%	59%	37	9	86%	79%	58	22

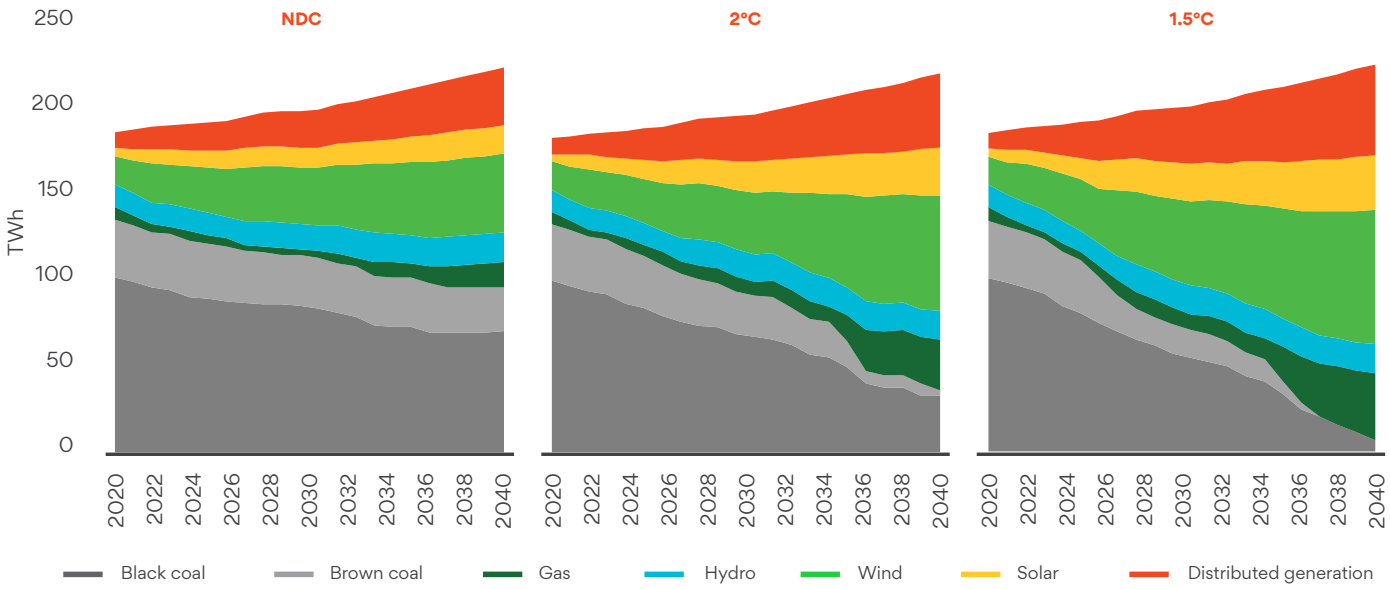
Generation outcomes

The primary driver of emissions reduction is the effective carbon price and a long-term target that delivers stability to the market through long-term policy certainty. Installation of renewables is the lowest cost form of emissions reduction in all scenarios. Renewable generation is built in line with coal retirements, alongside firming capacity, in response to price signals. The mixture of wind versus solar built into the modelling is an iterative result of the most economic plant at the time of build.

Renewables are initially firmed with existing capacity, then new fast-start gas or storage (either battery or pumped hydro storage), depending on prevailing market conditions and costs. Renewables are also partially firmed by increased interconnection.

Both gas and storage have a role to play in capacity replacement, because while the capacity cost of batteries eventually falls below gas turbines, increasing amounts of batteries also compete away the value they can capture, reducing their overall value. Longer duration firming (from hours to days) is also required in the modelling to maintain system security for extended periods of high demand and/or low renewable generation events. Generally, the higher the abatement task the greater the requirement of both storage and gas. At very high levels of renewables penetration, fast-start gas generation that can handle multiple start-stop events becomes more important than lower carbon intensity generation.

NEM energy supply by generation source

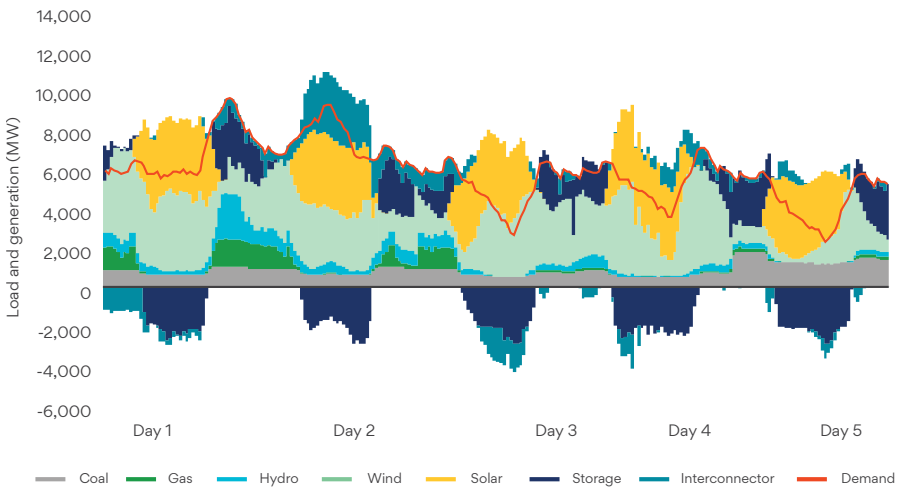


This chart demonstrates an example week in the scenario analysis after most of the coal fleet in NSW is retired under the 1.5°C scenario. The market balances with significant renewable generation, providing low-cost energy, optimised to demand with storage (batteries and pumped hydro), with gas providing system security for periods ranging from a few hours to most of the day. Each technology plays a role and an efficient outcome is a balance of many technologies.

Resolving the energy trilemma of energy affordability, decarbonisation and reliability of supply is achievable, but requires a market signal that values capacity, carbon intensity and flexibility in supply.

Without the certainty of a price signal, it is difficult for private investors to commit capital to the type of long-term projects required to minimise costs and achieve these goals. These price signals do not need to be bundled into one price but do need to work together to provide clear signals to investors. To ensure the most efficient system and minimise costs, a clear market signal must be provided. Out-of-market signals, such as subsidies, will invariably be passed directly to the customer in the form of higher electricity prices.

An example week in summer in 2035 (half-hourly)



Pricing outcomes

Carbon prices range from $15/tonne in the NDC scenario to a maximum price of $80/tonne under the 1.5°C scenario. Despite the wide range of carbon prices, wholesale electricity prices for all scenarios modelled average within $7/MWh of each other over the entire 2020 to 2040 period. This is due to the internalisation of the carbon price between generation units with a closed baseline and credit scheme.

As generation is bid into the market at SRMC plus a premium to cover overhead costs, the ageing coal fleet faces increased operating costs while the low SRMC of renewable generation leads to lower spot prices. The inevitable retirement of coal under all scenarios and increased renewable generation creates more daily volatility within the spot market. Gas generation can fill the energy and capacity shortfall, while increased spot market volatility drives more storage investment to capture intra-day price volatility. As volatility dampens, ageing coal plants once again face challenging and often uneconomic operating conditions.



Portfolio valuation results

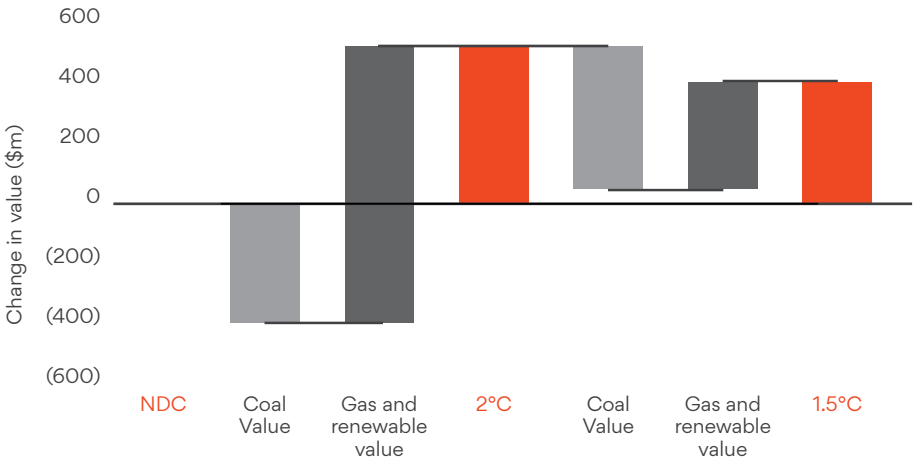
Importantly, this analysis covers Origin's existing owned and committed contracted generation portfolio only. It does not consider any future expansion of or change in the portfolio (e.g. continued growth in renewables).

We have committed to close Eraring by 2032. A significant proportion of our gas fleet also reaches its technical end of life during the early to mid-2030s. This rolling off of capacity reduces our baseload exposure to the high carbon pricing scenarios and also provides us with line of sight into suitable replacement capacity to capitalise on future market conditions.

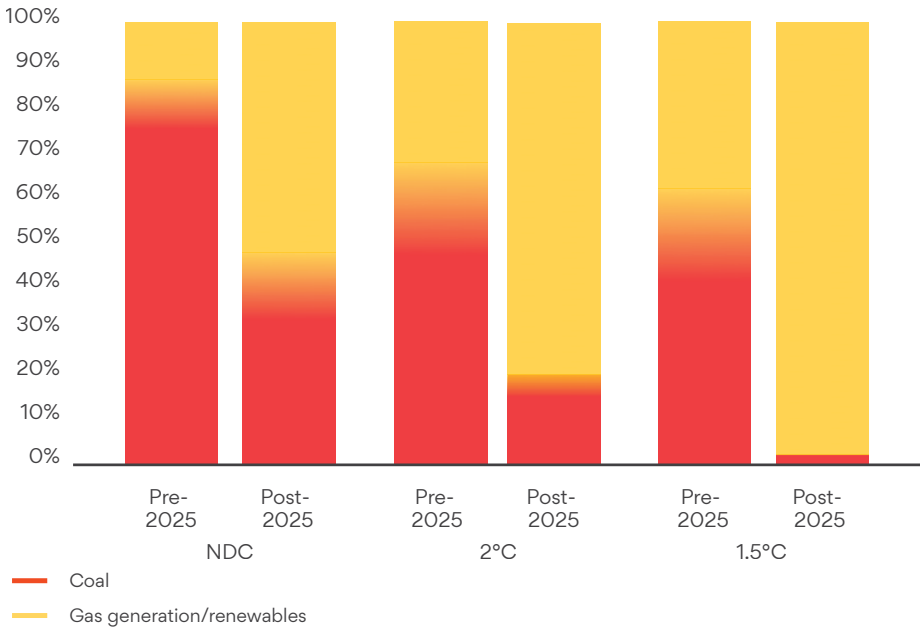
Under the 2°C scenario, we estimate our wholesale generation portfolio would increase in value relative to the NDC scenario[23], with the benefit to our renewable and gas portfolios outweighing the increased carbon cost to our single coal-fired generation plant, Eraring. The carbon price realises a higher underlying value for our PPAs and enables our lower heat rate gas plants to increase output against higher intensity coal, while capacity value increases in the back end as the market tightens.

Under the 1.5°C scenario, the value of our generation portfolio would decline relative to the 2°C case, however the overall portfolio value would still display a net increase compared to a low-action NDC case. Capacity value is realised earlier under the 1.5°C scenario as coal retirements across the NEM are brought forward and the higher carbon price brings increased value to our renewables and gas portfolio, helping to offset the decline in value from Eraring.

Origin climate change scenarios - change in net present value



Generation value over time and scenario



While the value of Eraring would decline under both the 2°C and 1.5°C scenarios, it would retain a net positive value due to earnings in the early years. It would still be an important asset that provides secure and affordable baseload power in the short- to medium-term.

The sensitivity of these values is subject to a number of exogenous variables, ranging from individual competitor decisions to the overarching energy policy framework, which could change the results. The valuation approach lets economic principles dictate the modelling outcomes and so we believe it represents a fair view of our portfolio resilience.

This analysis only considers the portfolio as it currently operates. Origin regularly assesses different options to prepare our portfolio for the energy transition and eventual closure of Eraring, including:

- unit cycling or two-shifting at Eraring;
- continued growth in renewables;
- the expansion of Shoalhaven;
- brownfield opportunities, such as upgrades or expansions of existing gas fleet with fast-start technologies (eg: turbine replacement and upgrade at Quarantine Power Station); and
- increased demand from electrification.

While these opportunities haven't been explicitly valued in this analysis, we are consistently working towards cost-effective options to ensure the resilience of our portfolio to a carbon constrained future.

This 1.5°C scenario analysis further demonstrates that our decarbonisation strategy and independently validated and approved science-based decarbonisation targets, remain aligned with the goals of the Paris Agreement.

[23] In our 2017 climate scenario modelling analysis, we also included a BAU pathway. This scenario was excluded from this report as the influx of renewable generation capacity under the LRET, in conjunction with state-based renewable targets, energy-efficiency schemes and continued growth of behind-the-meter solar PV, are projected to deliver electricity emissions in line with the NDC scenario. We note that the electricity sector alone meeting its share of an NDC target is insufficient for Australia to meet our Paris commitments. For more information, see the United Nations Environment Programme, (2018), Emissions Gap Report. wedocs.unep.org/bitstream/handle/20.500.11822/26879/EGR2018_ESEN.pdf?sequence=10.

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