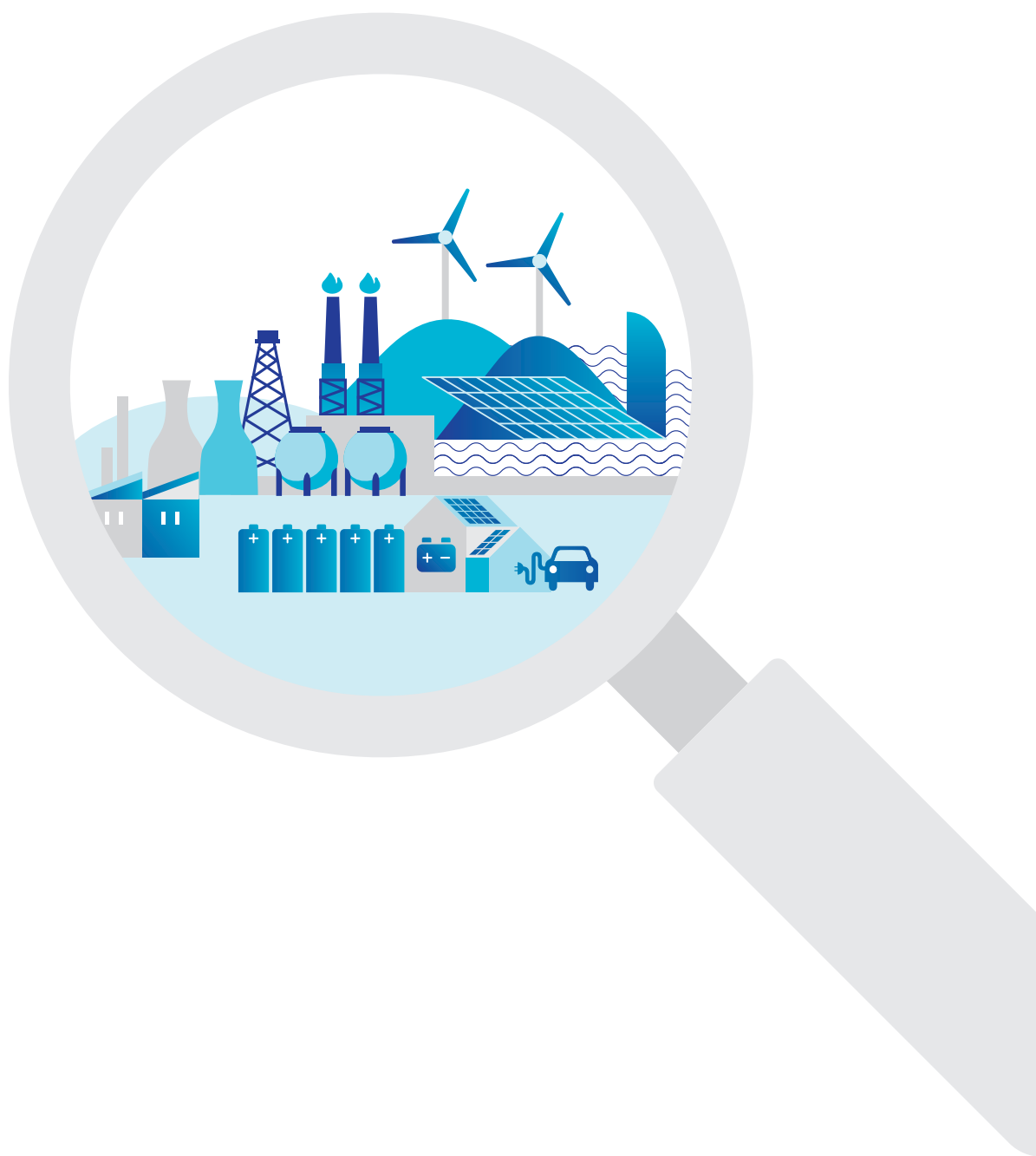




# FY19 Carbon Scenario Analysis



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## TCFD Framework

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In July 2017, the Task Force on Climate-Related Financial Disclosures (TCFD) released its final recommendations under the mandate of the G20 Financial Stability Board. These recommendations outline a voluntary framework (TCFD Framework) to promote better disclosure of climate-related financial risks.

This report forms part of AGL's disclosures under the TCFD Framework. A summary of AGL's governance and risk management processes in relation to climate change is available in the AGL FY19 Annual Report alongside key performance measures relating to AGL's greenhouse gas emissions.

# Executive summary

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This report provides the results of modelling the impacts of various renewable energy policies on the National Electricity Market (NEM) and the AGL generation portfolio to 2030.

To assist with strategic planning, during FY19 AGL modelled three scenarios aligned with various climate-related policy alternatives. Equivalent emission reduction outcomes and expected increases in temperature from pre-industrial levels were identified for each scenario.

The results of the analysis indicate that AGL's operated generation assets will continue to play an important role under each of the three scenarios modelled.

AGL's plans for the eventual closure of its coal-fired power stations by 2048 remain on track, and the scenarios indicate that AGL's current timeline is not inconsistent with reducing greenhouse gas emissions to a level consistent with limiting warming to below 2 degrees above pre-industrial levels.

During FY20, further scenario analysis will be undertaken to understand the impacts on AGL's portfolio and closure plans under scenarios that limit warming to below 1.5 degrees above pre-industrial levels.

The results presented in this report do not represent an expected or preferred view of the future. Rather, the model optimises the replacement of existing power station output with low-emission generation to minimise the overall costs of meeting demand given a range of specific assumptions. As such, the results should be taken as indicative only.

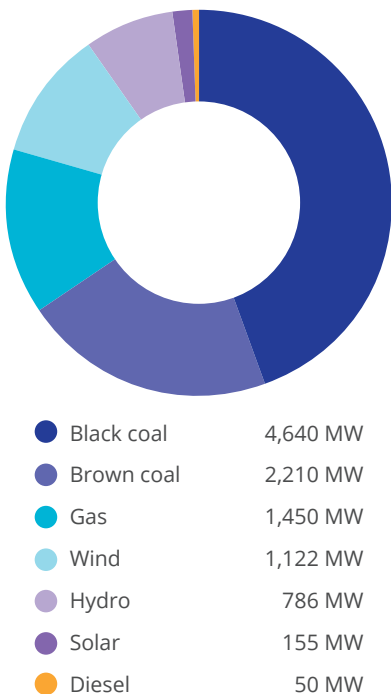
# 1. Introduction

AGL is a leading integrated energy business that has been operating for more than 180 years. AGL supplies electricity, gas and energy-related services to over 3.7 million customer accounts, including residential, business and wholesale customers. AGL operates Australia’s largest electricity generation portfolio with a total capacity of 10,413 MW, which accounts for around 20% of the total generation capacity within Australia’s National Electricity Market (NEM).

Over recent years AGL has been the largest ASX-listed developer of renewable energy projects, operating a portfolio of over 2,000 MW in FY19.

As shown in Figure 1, AGL’s current generation fleet is predominantly made up of black and brown coal assets. AGL’s operated scope 1<sup>1</sup> emissions account for approximately 8% of Australia’s total emissions. Over 95% of AGL’s emissions come from the combustion of coal for the generation of electricity.

**Figure 1: AGL operated generation portfolio FY19**



As Australia’s largest greenhouse gas emitter, AGL recognises it has a responsibility to be transparent about climate change and the risks and opportunities it poses to its business, the community and the economy more broadly.

AGL’s approach to transitioning to a low-carbon future is set out within the AGL Greenhouse Gas Policy. This policy acknowledges that Australia is moving to a carbon-constrained future and provides a framework within which greenhouse gas reduction activities will be structured, presenting a pathway for the gradual decarbonisation of AGL’s generation portfolio by mid-century. The commitments of AGL within this policy are not inconsistent with the goal of the Paris Agreement to limit warming to below 2 degrees celsius above pre-industrial levels.

## 1.1. Current policy framework

Under the Paris Agreement adopted in 2015, a declaration was made to mitigate risks associated with climate change. This agreement was a commitment by participating countries to a goal of reducing carbon emissions in a manner consistent with limiting global warming to less than 2 degrees above pre-industrial levels, with a concerted effort to constrain warming to less than 1.5 degrees.

The mechanism to achieve the Paris Agreement requires each participating country to set a Nationally Determined Contribution (NDC) to the reduction of emissions. The NDC is required to be reviewed and tightened every five years. Australia’s current NDC comprises a reduction of Australia’s emissions by 26-28% of 2005 levels by 2030.

Globally it is estimated that current NDCs are not consistent with limiting warming to below 2 degrees above pre-industrial levels.<sup>2,3</sup>

Both national and state-based renewable energy policies are in place in Australia to increase the proportion of renewable electricity generation in various jurisdictions. These comprise:

- The Large-scale Renewable Energy Target (LRET), a federally legislated target requiring 33,000 GWh of Australia’s electricity to be produced from renewable energy sources by 2020. The LRET works by allowing large-scale power stations to create large-scale generation certificates for every megawatt hour of power they generate. Certificates are then purchased by electricity retailers and submitted to the Clean Energy Regulator to meet the retailers’ legal obligations under the LRET.
- The Queensland Renewable Energy Target (QRET) is the current Queensland Government policy to achieve 50% of generation in Queensland from renewable energy sources by 2030. This has not yet been legislated.
- The Victorian Renewable Energy Target (VRET) is the current Victorian Government policy to achieve 50% of generation in Victoria from renewable energy sources by 2030. The Victorian Government has thus far only legislated a target of 40% renewable generation by 2025.

1. Scope 1 emissions are direct emissions (eg burning coal).

2. <https://climateactiontracker.org/global/temperatures/>

3. United Nations Framework Convention on Climate Change Secretariat (2016), 'Aggregate effect of the intended nationally determined contributions: an update.'




## 2. Modelling approach

The three scenarios below have been chosen by AGL as they are representative of differing policy frameworks that have been proposed in Australia and considered to be reasonably possible. They are intended to give an understanding of various ways forward for AGL in the context of the overall electricity sector.

This analysis has been undertaken as part of AGL's annual strategic planning cycle to identify risks and opportunities in our external operating environment to facilitate the business's strategic decision making and to drive resource allocation. This process supports AGL's strategic priorities to pursue growth, transformation and a social licence to meet and exceed rising community expectations.

Table 1 below outlines the scenarios and assumptions behind them.

**Table 1: Scenarios modelled within the NEM**

Scenarios	 Slow Change	 State Targets	 Deep Renewables
<b>Overview</b>	<i>'The market is slow to adapt to a more carbon constrained future'</i> Governments do not introduce new measures to encourage renewable energy.	<i>'The current path forward into a renewable-focused world'</i> State governments legislate already announced renewable energy targets.	<i>'Consistent renewable policy targets across the NEM being achieved'</i> Accelerated closure of thermal plant resulting from higher renewable energy targets.
<b>Renewable policy</b>	Current LRET: • 33 TWh of renewable energy generation by 2020.	Current LRET plus QRET and VRET: • Additional renewable generation to 50% by 2030 in Queensland and Victoria	Effective LRET increase to 50% renewable energy by 2030
<b>General assumptions</b>	~2.7 GW of capacity retiring by 2030 Up to ~460 MW in interconnection capacity Snowy 2.0 completed	~3.5 GW of capacity retiring by 2030 Up to ~1.2 GW in interconnection capacity Snowy 2.0 and SA-NSW interconnector completed	~6.5 GW of capacity retiring by 2030 Up to ~1.2 GW in interconnection capacity Snowy 2.0 and SA-NSW interconnector completed
<b>Closure assumptions</b>	AGL Torrens A Power Station – staged closure 2019-2021 Mackay Gas Power Station – closure late 2021 AGL Liddell Power Station – closure from 2022	AGL Torrens A Power Station – staged closure 2019-2021 Mackay Gas Power Station – closure late 2021 AGL Liddell Power Station – closure from 2022 Millmerran Power Station – closure 2026	AGL Torrens A Power Station – staged closure 2019-2021 Mackay Gas Power Station – closure late 2021 AGL Liddell Power Station – closure from 2022 Millmerran, Yallourn & Vales Point power stations – closures 2026

## 2. Modelling approach (continued)

Three different scenarios for the outlook of the NEM were studied to understand the impact on the market and AGL assets until 2030. Each scenario represented a different policy approach that state and/or federal governments may implement over the short term. The impact was assessed from two dimensions: the operational impact on assets; and the impact on future revenue. PLEXOS<sup>4</sup> market modelling software was used to model generation at half-hourly intervals whilst imposing the constraints in Table 1 along with internal AGL views on fuel costs. The objective of the model is to minimise cost whilst meeting the imposed constraints.

The three scenarios reflect different emissions trajectories over time. The scenarios do not assume one policy is more beneficial than another; it is assumed the policy commitment will occur and the impact on the market itself is studied. The primary difference between the three scenarios is the extent to which new utility-scale solar and wind farm projects are developed over the modelling periods.

All scenarios model an electricity demand consistent with the Australian Energy Market Operator (AEMO) neutral demand forecast as published in the 2018 Electricity Statement of Opportunities (i.e. a relatively flat electricity demand curve over the modelling horizon). Various upgrades to interconnection in the NEM were included based on the AEMO Integrated System Plan 2018.<sup>5</sup> Some discretion on the timing of these upgrades was applied for each scenario. The Snowy 2.0 project was also included in all scenarios.

The Slow Change scenario represents limited new build of renewable generation. All currently committed and probable renewable projects are assumed to be constructed under this scenario. Additional new build renewables are only included where financially viable within the model.

In the State Targets scenario, the model assumes that in addition to the Slow Change scenario, renewable generation is also built in Victoria and Queensland to meet VRET and QRET.

In the Deep Renewable scenario, it is assumed that policy changes at the national level require additional renewable generation to be built on top of that required for the State Targets scenario to achieve a policy outcome of approximately 50% renewable energy by 2030 for the whole of the Australia.

For all three scenarios, outcomes in FY20-FY22 are based on AGL's current forecasting, which considers current Australian government policy and known short-term constraints such as availability of fuel. The scenarios begin to diverge from FY23.

Climate Action Tracker (CAT)<sup>6</sup> publishes data relating to effort sharing pathways for emissions reduction on a country basis. To determine which pathway each scenario best represented, CAT data representing carbon budgets for 2030 for each pathway was used. For the purpose of this analysis it was assumed that the proportion of Australia's emissions arising from the NEM would remain consistent at 28% from FY18 to 2030. This proportion was applied to each CAT budget for each pathway. It is acknowledged that this only gives an indication of where each of the three scenarios fits within a climate change context.

4. For further information on PLEXOS modelling, see: <http://energyexemplar.com/software/plexos-desktop-edition/>




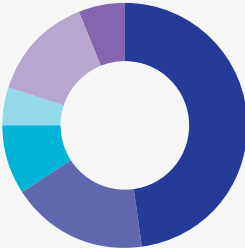
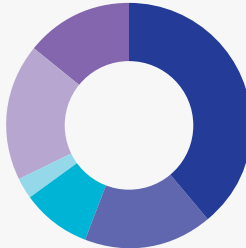
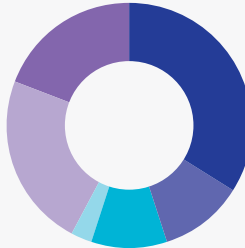
5. [https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning\\_and\\_Forecasting/ISP/2018/Integrated-System-Plan-2018\\_final.pdf](https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2018/Integrated-System-Plan-2018_final.pdf)

6. <https://climateactiontracker.org/countries/australia/>

# 3. Results

The outputs of the modelling for the NEM and AGL are summarised in Table 2 and Table 3 respectively.




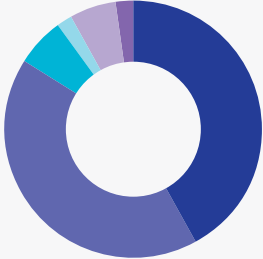
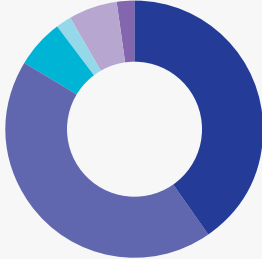
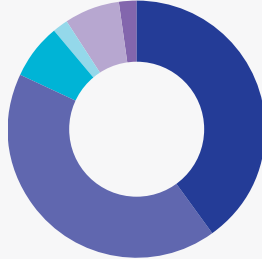
**Table 2: Modelling results for the NEM at FY30**

Scenarios	 Slow Change	 State Targets	 Deep Renewables
<b>Indicative climate change scenario</b>	Inconsistent with a 2-degree scenario	Potentially consistent with a 2-degree scenario <sup>7</sup>	Potentially consistent with a 2-degree scenario <sup>7</sup>
<b>Utility-scale renewable penetration</b>	29%	41%	50%
<b>Emissions changes</b>	18% reduction from 2005 levels	29% reduction from 2005 levels	45% reduction from 2005 levels
<b>Utility-scale battery storage</b>	0.2 GW	0.2 GW	0.2 GW
<b>Distributed battery storage</b>	1.1 GW	1.1 GW	1.1 GW
<b>Coal generation retirements</b>	2.3 GW	3.1 GW	6.1 GW
<b>Generation output FY30</b>	190 TWh	194 TWh	196 TWh
<b>Generation mix FY30</b>	 <ul style="list-style-type: none"> <li>● Black coal 48%</li> <li>● Brown coal 18%</li> <li>● Hydro 9%</li> <li>● Gas 5%</li> <li>● Wind 14%</li> <li>● Solar 6%</li> </ul>	 <ul style="list-style-type: none"> <li>● Black coal 39%</li> <li>● Brown coal 17%</li> <li>● Hydro 9%</li> <li>● Gas 3%</li> <li>● Wind 18%</li> <li>● Solar 14%</li> </ul>	 <ul style="list-style-type: none"> <li>● Black coal 34%</li> <li>● Brown coal 11%</li> <li>● Hydro 10%</li> <li>● Gas 3%</li> <li>● Wind 23%</li> <li>● Solar 19%</li> </ul>
<b>Operational impacts</b>	<ul style="list-style-type: none"> <li>• Less investment in renewable capacity required over the scenario timeframe</li> <li>• Less risk of grid instability as more large synchronous capacity (i.e. baseload coal) remains in the NEM</li> </ul>	<ul style="list-style-type: none"> <li>• Increased requirements for firming capacity to support increased renewables in the NEM</li> <li>• Risks from disparate uncoordinated energy policy</li> <li>• Opportunities in new behind-the-meter markets emerge</li> <li>• Increasing use of large-scale storage (e.g. batteries and pumped hydro) to provide firming capacity</li> <li>• Increasing use of gas peaking generation</li> </ul>	<ul style="list-style-type: none"> <li>• Increased requirements for firming capacity to support increased renewables in the NEM</li> <li>• Increased ramping requirements of existing coal generation assets</li> <li>• Increased investment in renewable generation required</li> <li>• Opportunities in new behind-the-meter markets emerge</li> <li>• Increasing use of large-scale storage (e.g. batteries and pumped hydro) to provide firming capacity</li> <li>• Increasing use of gas peaking generation</li> </ul>

7. Dependant on international NDC's and action in Australia's other economic sectors.

### 3. Results (continued)

Table 3: Modelling results for AGL at FY30

Scenarios	 Slow Change	 State Targets	 Deep Renewables
Utility-scale renewable penetration	10%	10%	11%
Emissions changes <sup>8</sup>	14% reduction from FY16 levels	19% reduction from FY16 levels	23% reduction from FY16 levels
Operated generation output FY30	37.4 TWh	35.5 TWh	34.0 TWh
Operated generation mix FY30	 <ul style="list-style-type: none"> <li>● Black coal 42%</li> <li>● Brown coal 42%</li> <li>● Hydro 6%</li> <li>● Gas 2%</li> <li>● Wind 6%</li> <li>● Solar 2%</li> </ul>	 <ul style="list-style-type: none"> <li>● Black coal 40%</li> <li>● Brown coal 43%</li> <li>● Hydro 7%</li> <li>● Gas 2%</li> <li>● Wind 6%</li> <li>● Solar 2%</li> </ul>	 <ul style="list-style-type: none"> <li>● Black coal 40%</li> <li>● Brown coal 42%</li> <li>● Hydro 7%</li> <li>● Gas 2%</li> <li>● Wind 7%</li> <li>● Solar 2%</li> </ul>

In the Slow Change scenario, emissions reductions are relatively limited due to the flat demand curve and limited retirement of thermal generation assets during the modelling period. The impact to existing assets is negligible, and is unlikely to force mothballing or early retirement of existing assets other than already announced closures.

Under the State Targets scenario, there are significant decreases in emissions across the NEM. The model indicates a high uptake of distributed solar, particularly in Queensland, which is likely to negatively affect existing coal-based generators. It is possible some black coal power stations may be mothballed, operated seasonally and/or retired prematurely due to both the reduction in demand (due to increased generation from renewable sources) and the subsequent physical cycling required of units. This cycling is likely to occur as renewable generation starts to be bid into the market at prices below that of black coal generation making it less financially viable. The cycling is also physically problematic for the plant causing additional wear and tear and increasing maintenance costs.

Additionally, in Victoria increased renewable generation is likely to reduce the output from more expensive black coal generation in New South Wales rather than reducing the output of Victorian (brown coal) coal-fired generators. The impact on existing coal assets in Victoria is more limited as wind is the predominant new build over this horizon, reducing the impact on intraday cycling as seen by high solar uptakes. The timing and nature of interconnection may speed up or alternatively alleviate these issues.

In the Deep Renewable scenario, an approximate 45% reduction of emissions from 2005 by 2030 is likely to occur. This produces a relatively aggressive emissions reduction trajectory out to 2030. As discussed above, significant pressure is seen on coal-based generation in Queensland. Pressure is also put on black coal generation in New South Wales as generation is displaced by renewables resulting in lower thermal generation volumes and reduced prices. As in the case above it is likely that black coal in Queensland and/or New South Wales will be mothballed, operated seasonally and/or retired prematurely due to the reduction in generation volumes and the physical constraints placed on unit operation.

8. This is calculated based on emissions from our generation portfolio only and excludes emissions from gas production and storage and other emissions



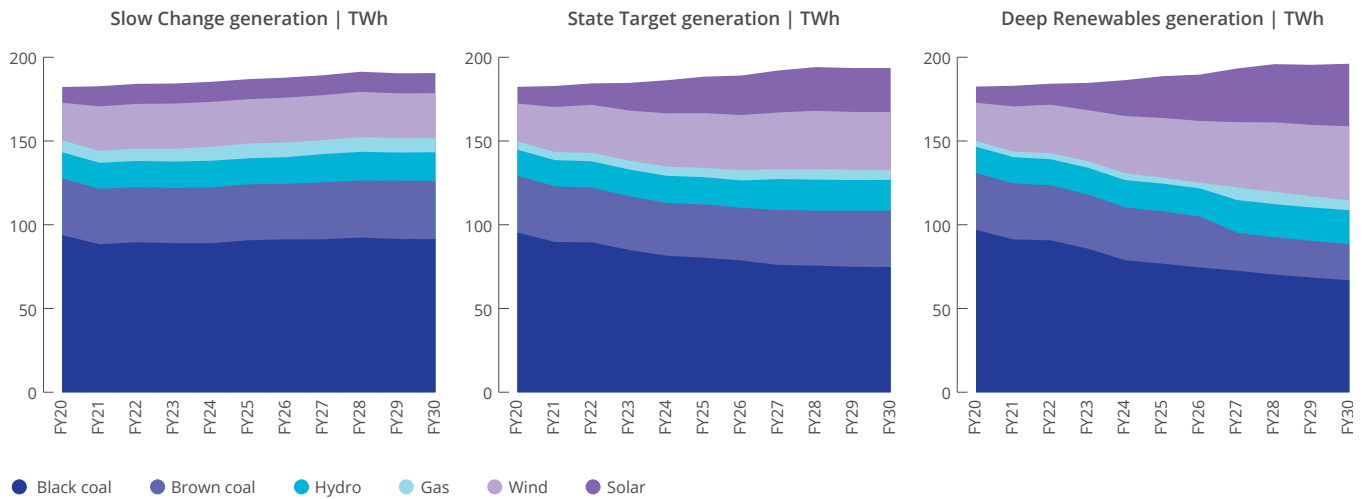
### 3. Results (continued)

#### 3.1. Generation and greenhouse gas emissions implications

As expected, the modelled constraints in each scenario show a material impact on the generation mix within the NEM. Under all scenarios, renewable penetration continues to increase, with the majority of the increase coming from utility-scale solar and wind installations. This corresponds to a reduction in required generation from thermal coal assets, and associated emission reductions across the sector. Figure 2, below, shows that under each scenario there is a reduction in coal-fired output and a large increase in renewable energy generation.

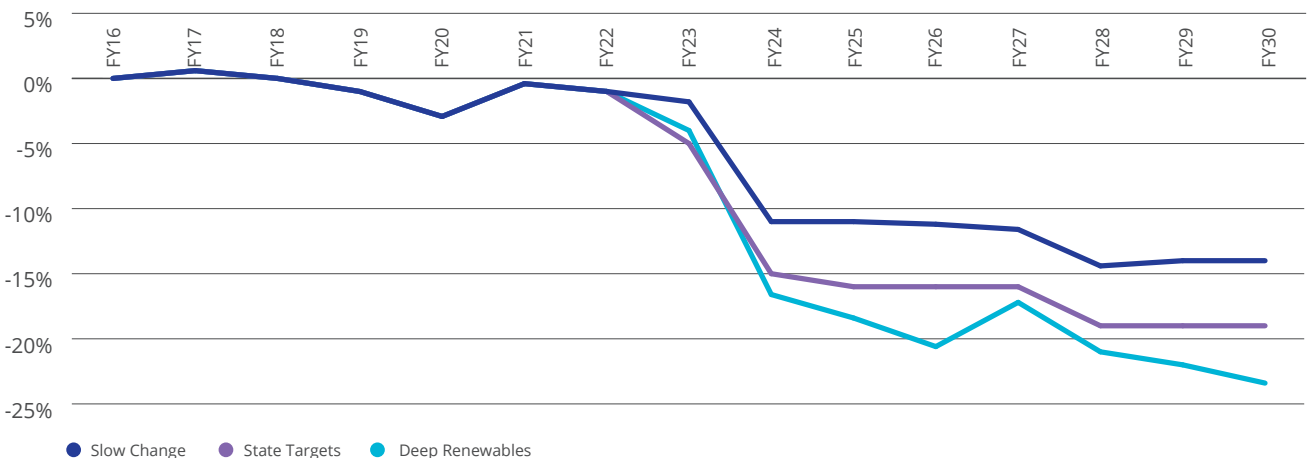
Additionally, under all three scenarios there is limited uptake of base-load gas-fired generation with a greater need for peaking plants. This reflects the cost of gas remaining relatively high in the modelled period to 2030. However, with such significant uptake of renewable energy there are limitations on the ‘ramping’ capabilities of existing coal-fired generators. To overcome these limitations grid-based and residential energy storage is used to complement intermittent renewables across all scenarios.

Figure 2: NEM generation across each scenario



Similarly, across AGL’s generation fleet emissions reductions are linked to reduced generation from thermal coal assets. Figure 3 shows the changes in AGL’s emissions profile under each of the scenarios. The significant decrease from FY23 to FY24 corresponds to the previously announced planned closure of Liddell Power Station<sup>9</sup>, and the uptick in the Deep Renewable scenario accounts for the additional generation required from AGL’s coal fleet to compensate for other assumed (non-AGL) coal-fired generation plant closures.

Figure 3: AGL percentage emissions change from FY16 baseline<sup>10</sup>



9. For modelling purposes a staged closure is assumed to occur from 2022.

10. Note the decline in emissions in FY20 is due to the outage at Unit 2 of the Loy Yang A power station communicated to the market on 7 June 2019.

## 3. Results (continued)

As shown in Figure 3, the Deep Renewable scenario leads to a significant reduction in emissions arising primarily from reduction in generation from existing coal assets as renewable generation starts to be bid into the market at a price lower than that of coal. In these higher renewable penetration scenarios this leads to an inherent requirement of increased flexibility for AGL's coal assets, as well as significant opportunity for providing storage options including pumped hydro and behind-the-meter batteries.

The Deep Renewable scenario demonstrates that continued operation of AGL's Bayswater and Loy Yang A power stations is not inconsistent with a 2 degree scenario. The scenarios analysed the thermal and cost efficiencies of AGL's Bayswater and Loy Yang A power stations compared to other (non-AGL) assets, with the modelling results showing that, on a sector basis, the policy constraints modelled are more economically met by the closure of non-AGL thermal assets in advance of the already announced closure dates for AGL's thermal assets.

### 3.2. Financial implications

AGL has considered the outcomes of the modelled scenarios in 2030. It is anticipated that the aggregate value of AGL's electricity generation fleet will reduce under both the State Targets and Deep Renewables scenarios.

Any change to the planned closure dates of AGL's coal-fired generation plants as a result of climate change and associated policies may also have a material impact on the National Electricity Market and may result in a material reduction to AGL's estimated cash inflows.

However, AGL anticipates that a rapid transition away from coal generation would place greater reliance on low-cost baseload generators. Accordingly, under both the State Targets and Deep Renewables scenarios the Loy Yang A and Bayswater power stations would likely be deemed necessary for market reliability and would therefore maintain significant value to AGL to 2030.

Additionally, AGL sees financial opportunities arising from an economy-wide transition to a low-carbon future, such as increasing demand in the NEM arising from the electrification of the transport sector, as well as from the sale of new retail offerings including residential batteries.

More generally, AGL's recoverable value estimates used in its impairment of assets analysis considers climate change risk through the adjustment of cash inflows associated with the planned closure of AGL's Liddell Power Station. This recoverable value estimate demonstrates that the carrying value of AGL's Group Operations business unit is not impaired in the current year.

AGL recognises that there is an increased pace of change in the energy industry and associated political landscape. AGL will continue to work towards incorporating quantification of the financial impact of climate change and related policies within our annual financial filings in accordance with Australian Securities and Investments Commission (ASIC), Australian Prudential Regulation Authority (APRA), and Australian Accounting Standards Board (AASB) recommendations.

## 4. Conclusion

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This report outlines the results of modelling three scenarios relating to Australian energy and climate policy, which may be likely to occur over the next decade. These scenarios have been modelled by AGL to understand the impacts of varying policy alternatives at both a state and federal level on both the NEM and AGL's business.

AGL is continuing to focus on deriving value from its business as the electricity sector transitions to a decarbonised future. AGL is focusing on particular strategies which have been identified from this process including further investment in and enabling of renewable assets, as well as developing a pipeline of flexible generation assets such as pumped hydro and utility-scale batteries.

As renewable energy displaces traditional dispatchable generation assets without supplying other services such as strategic reserve, operating reserve, inertia and system strength, AGL will seek to build alternatives while also continuing to improve the flexibility of existing coal assets.

AGL will also continue to work with its customer base to develop offerings such as batteries to enable customers to actively participate in the transition.

AGL's plans for closure of all coal-fired power stations by 2048 remains on track and the scenarios indicate that AGL's current timeline is not inconsistent with reducing greenhouse gas emissions to a level consistent with limiting warming to below 2 degrees above pre-industrial levels.

