ENERGY
www.csiro.au

Review of Progress to Achieving Targets Under Section 7 of the Climate Change and Greenhouse Emissions Reduction Act 2007

EP184758
June 2018

Prepared for the SA Department for Environment and Water

Citation

CSIRO (2018). *Review of Progress to Achieving Targets Under Section 7 of the Climate Change and Greenhouse Emissions Reduction Act 2007*, Report No. EP184758, June.

Contents

Figures

Tables

Acknowledgments

The CSIRO authors (Luke Reedman and Paul Graham) acknowledge the assistance of Department for Environment and Water personnel (Louisa Perrin), CSIRO colleagues (Tristian Kemp, Sigvart Evgen), Rob Kelly (ClimateWorks Australia), Kathryn Smith (ex-CSIRO) and Anna Krook-Riekkola (Luleå University of Technology) in preparing this report.

Executive summary

The Government of South Australia *Climate Change and Greenhouse Emissions Reduction Act 2007* includes as one of its requirements under Section 7 (5) that a report be prepared to assess the extent to which any determination or target made or set under Section 5 of the Act is being achieved and, if it appears relevant, should be revised. The report that follows is CSIRO's independent assessment to meet this requirement.

Part 2 of the Climate Change and Greenhouse Emissions Reduction Act 2007 (the Act) specifies a principal target to achieve a reduction in greenhouse gas emissions within the State of South Australia, as well as two related targets that promote the generation and use of renewable sources of energy. The Act also instructs the Minister for Climate Change (the Minister) on the operation of these targets. Specifically, the Act states in Part 2:

Part 2 – Targets

5—Targets

(1) The principal target under this Act is to reduce by 31 December 2050 greenhouse gas emissions within this State by at least 60% to an amount that is equal to or less than 40% of 1990 levels.

(2) Two related targets under this Act are—

(a) to increase the proportion of renewable electricity generated so that it comprises at least 20% of electricity generated in the State by 31 December 2014;

(b) to increase the proportion of renewable electricity consumed so that it comprises at least 20% of electricity consumed in the State by 31 December 2014.

(3) The Minister may, in connection with the operation of subsections (1) and (2) for the purposes of any other provision of this Act—

(a) determine the method for calculating greenhouse gas emissions for the purposes of setting relevant 1990 levels (the ***baseline***), and then determine a figure that represents that baseline;

(b) determine the method for calculating any reduction in greenhouse gas emissions;

(c) set sector-based targets and additional interim targets;

(d) set specific baselines for particular areas of activity (as components of the overall baseline);

(e) make other determinations that assist in measuring greenhouse gas emissions within the State.

An additional target was made by the Minister under Part 2 of the Act stating "33.3% of South Australia's electricity generation to come from renewable energy by 2020". The renewable electricity consumption target, for 2014, was not renewed.

The Minister is required, on a two-yearly basis, to prepare a report on the operation of the Act. The first report, and thereafter every alternate report, must incorporate a report from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) that:

- Summarises CSIRO's assessment of the extent to which any determination or target made or set under Part 2 of the Act is being achieved and, if it appears relevant, should be revised; and
- Provides advice on the method for calculating the 1990 baseline for the greenhouse gas target consistent with Sections 5 (4) (b) and Section 5 (4) (c) of the Act.

This document reports the assessment of CSIRO in relation to the third of these four-yearly reports. The key findings are listed below.

As of 2016, greenhouse gas emissions in South Australia have decreased by 20% compared to 1990 levels.	• In recent years, energy sector GHG emissions have been declining mainly due to the increased deployment of large-scale wind generation and rooftop solar photovoltaic (PV) systems, especially residential based systems. • In recent years, net GHG emissions from LULUCF have been negative (GHG emissions sequestered by LULUCF sinks exceeding GHG emissions from LULUCF sources), contributing to the decline.
As of 2017, the proportion of South Australia electricity generation that was generated using renewables was 48.9%.	• The proportion of renewable electricity generation in South Australia has increased significantly in recent years • South Australia surpassed its current target for renewable electricity generation (33.3% of South Australia's electricity generation to come from renewable energy by 2020) during 2013/14. The current proportion of renewable energy generation is slightly below the policy target of 50% renewable generation by 2025.
Many jurisdictions have, or are considering, legislating long-term net zero GHG emission targets	• The legislation of net zero GHG reduction targets is a recent occurrence • The Australian Capital Territory, Victoria have legislated long-term net zero GHG reduction targets and internationally, Sweden has a legislated net zero target.

Part I Assessment

1 Greenhouse gas emissions target

1.1 Current progress

For the purposes of the Act, the target pertaining to "… *greenhouse gas emissions within this State*" requires the establishment of the SA greenhouse gas (GHG) inventory as a time series from the base year 1990.

Total SA GHG emissions are calculated as total SA GHG emissions, including Land Use, Land Use Change and Forestry (LULUCF) sources, less LULUCF sinks.

The Australian Greenhouse Emissions Inventory System (AGEIS) provides annual GHG emissions data for all states and territories. The Department of the Environment and Energy (DoEE) annually revises the State and Territory Greenhouse Gas Inventories (STGGIs). The DoEE updates emission factors and methodologies when new information or more accurate methodologies become available and revises figures back to 1990 to ensure time series consistency. Re-calculation is an obligation under the United Nations Framework Convention on Climate Change (UNFCCC).

For this reason, historical GHG emissions data may change. The progress to target is assessed using the latest data available.

Australia's *National Inventory Report 2016* (DoEE, 2018a) contains national greenhouse gas emissions estimates for the period 1990-2016 compiled under the rules for reporting applicable to the UNFCCC and under the Kyoto Protocol. The two reports differ in their categorisation for LULUCF which has implications for emissions calculations for sub-jurisdictions.

The data made available on the Australian Greenhouse Emissions Information System (AGEIS) is compiled using reporting rules applicable for the Kyoto Protocol categories for LULUCF sub-classification. The *State and Territory Greenhouse Gas Inventories 2016* report (published in February, 2018) provides a data set based on United Nations Framework Convention on Climate Change (UNFCCC) accounting rules for LULUCF sub-classification. The Australian National Greenhouse Accounts are consistent with measuring progress in achieving Australia's 2030 target and Paris Agreement commitments. The UNFCCC classification system provides for the inclusion of a broader, more comprehensive set of lands than under the Kyoto Protocol and more readily permits the identification of emissions from land clearing events (DoEE, 2018b).

Table 1 presents total GHG emissions in Gigagrams (Gg) of carbon-dioxide equivalent (CO_2-e) for South Australia for recent selected years relative to the 1990 baseline. Total net emissions for both UNFCCC and Kyoto Protocol classifications for LULUCF are provided for completeness. The South Australian Government will monitor progress against the legislated 2050 target consistent with the Australian Government Paris Agreement targets (i.e. UNFCCC).

Table 1: SA greenhouse gas emissions 1990-2016

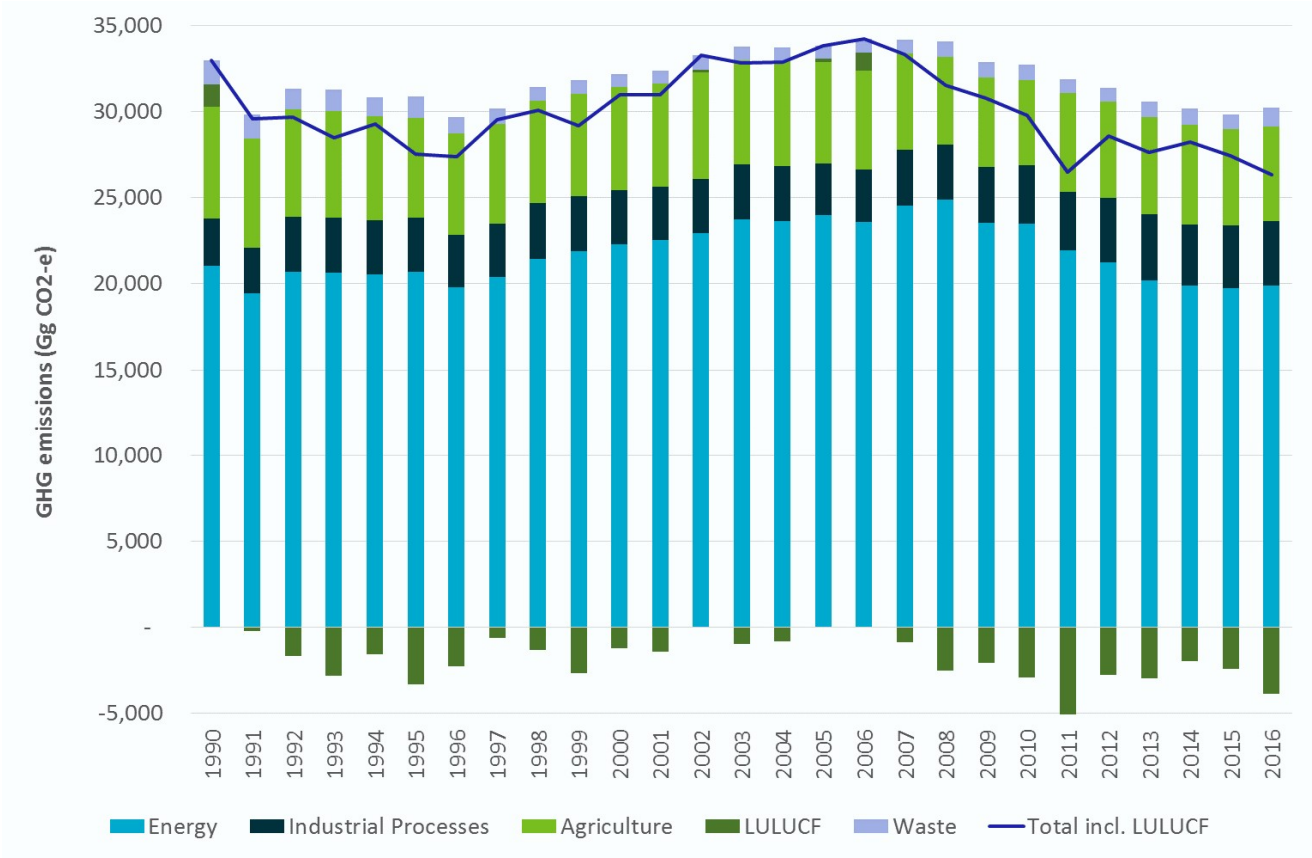
SA GHG Emissions (Gg CO2-e)	1990	2012	2013	2014	2015	2016
Total GHG emissions with land use, land-use change and forestry (UNFCCC)	32,948	28,680	27,621	28,208	27,430	26,346
Change since 1990 (UNFCCC)		-13.0%	-16.2%	-14.4%	-16.7%	-20.0%
Total GHG emissions with land use, land-use change and forestry (KP)	33,302	28,851	27,666	27,972	27,460	26,419
Change since 1990 (KP)		-13.4%	-16.9%	-16.0%	-17.5%	-20.7%

Source: Australian Greenhouse Emissions Inventory System (AGEIS) http://ageis.climatechange.gov.au [accessed 2 May 2018] and the UNFCCC data set provided to the Department for Environment and Water.

The SA GHG Inventory shows that GHG emissions have decreased by 20.0% under the UNFCCC methodology and 20.7% under the Kyoto Protocol methodology compared to 1990 levels. For consistency with the Act in regard to "greenhouse gas emissions within the State," there has been a change in approach to emissions associated with electricity generation that is imported into and exported from South Australia.

In previous years (pre 2017), the SA government included emissions from electricity generated in other states and imported by SA for the purpose of the calculation of the target. From 2017, these emissions have been excluded; they are not generated within the state and hence not consistent with the description "greenhouse gas emissions within the State" as stated in the Act. Similarly, the previous definition applied by SA government excluded emissions from exports in the estimate of GHG emissions for the State for the purpose of the calculation of the target. This is not consistent with the Act which explicitly refers to "greenhouse gas emissions within the State". Hence from 2017, the emissions relating to exports will be included.

Figure 1 presents total greenhouse gas emissions by headline category for South Australia since 1990. There has been significant movement in both the energy component and LULUCF emissions over that period. In recent years, energy sector GHG emissions have been declining mainly due to the increased deployment of large-scale wind generation and rooftop solar photovoltaic (PV) systems, especially residential based systems. At the same time, coal-fired power generation in South Australia ceased in May 2016 with the closure of the 546 MW Northern power station and the 240 MW Playford power station. There was also some reduction in gas-fired electricity generation with the second turbine at Pelican Point power station taken offline for upgrade in 2015, returning to service in 2017. Fuel combustion in manufacturing industries has also declined, and fugitive emissions have remained flat over the last five years. In contrast, transport sector GHG emissions have showed some moderate growth over the period.



Source: DoEE (2018b). This graph is based on the UNFCCC methodology for net LULUCF emissions.

Figure 1: SA greenhouse gas emissions by source and sink category, 1990-2016

In regards to the LULUCF category, net GHG emissions from LULUCF have been negative (GHG emissions sequestered by LULUCF sinks exceeding GHG emissions from LULUCF sources) over recent years, mainly due to plantations and natural regeneration of forest land, regrowth on deforested land and to a lesser extent cropland remaining as cropland.

1.2 Progress towards the 2050 Target

Assessing progress towards South Australia's greenhouse gas (GHG) target for 2050 is difficult and subject to considerable estimation risk given uncertainties regarding technological change, state and national policy decisions, investment behaviour, and the impact of the foregoing on consumer demand. The target for 2050 has been set in the context of broader national and interstate policy developments, and typically should complement general efforts around Australia to manage greenhouse gas emissions. Although these broader efforts will combine with the South Australian target to deliver lower emissions for Australia, the regulatory detail and commercial response is continuing to evolve and will affect the type and schedule of investments.

There are a number of factors that will influence this progress in the short-term (next five years). The main factor is the continued transformation of the electricity sector in South Australia through the increased penetration of renewable electricity generation which is being driven primarily by the national Renewable Energy Target policy. As of March 2018, South Australia had around 5200 MW of installed capacity of which around 1900 MW were renewable power plants (see Table 2) in addition to around 686 MW of rooftop solar PV capacity (AEMO, 2017a).

Table 2: South Australia power stations as at March 2018

Power station	Primary fuel type	Location	Cogeneration	Renewable	Year of commissioning	Unit details	Total capacity (MW)
Principal power stations [1]							
Torrens Island A	Natural gas	Torrens Island			1967	4x120,	480.0
Torrens Island B	Natural gas	Torrens Island			1977	4x200	800.0
Pelican Point	Natural gas	Pelican Point			2000	2x160 GT, 1x158 ST	478.0
Snowtown 2	Wind	North of Adelaide		•	2014	90x3	270.0
Quarantine	Natural gas	Torrens Island			2002	4x24, 1x128	224.0
Hallett GT	Natural gas	North of Adelaide			2002	4 x 16.4 3 x 17 2 x 17.3 2 x 24.8 1 x 27.5	228.0
Osborne	Natural gas	North-west of Adelaide	•		1998	1x120, 1x65	185.0
Lake Bonney 2	Wind	Lake Bonney		•	2008	53x3	159.0
Dry Creek	Natural gas	Adelaide			1973	3x52	156.0
Hallett 4 (North Brown Hill)	Wind	North Brown Hill		•	2011	63x2.1	132.3
Waterloo	Wind	Waterloo		•	2010	6 x 3.3 37x3	131.0
Snowtown	Wind	Snowtown		•	2008	47x2.1	98.7
Hallett 1 (Brown Hill)	Wind	Brown Hill, near Mount Bryan		•	2008	45x2.1	94.5
Mintaro	Natural gas	North of Adelaide			1984	1x90	90.0
Ladbroke Grove	Natural gas	Mt Gambier North			2000	2x43	86.0
Hallett 2 (Hallett Hill)	Wind	Hallett Hill		•	2010	34x2.1	71.4

Power station	Primary fuel type	Location	Cogeneration	Renewable	Year of commissioning	Unit details	Total capacity (MW)
Snuggery	Oil products	South-east of Adelaide			1978-97	3x21	63.0
Clements Gap	Wind	Clements Gap		•	2010	27x2.1	56.7
Hallett 5 (The Bluff)	Wind	Bluff Range		•	2012	25x2.1	52.5
Port Lincoln GT	Oil products	Port Lincoln			1998-00	2 x 25 1 x 23.5	73.5
Port Stanvac 1	Oil products	Lonsdale			2011	36x1.6	57.6
Angaston	Oil products	Angaston			2006	30x1.67	50.0
Lake Bonney 3	Wind	Lake Bonney		•	2010	13x3	39.0
Port Lincoln 2	Natural gas	Port Lincoln			2010	1x23.5	23.5
Lonsdale	Oil products	Lonsdale			2002	18 x 1.15	20.7
Hornsdale Power Reserve Unit 1	Battery storage	Hornsdale			2017	100MW, 129 MWh	100.0
Hornsdale Wind Farm Stage 1	Wind	Hornsdale		•		32 x 3.2	102.0
Hornsdale Wind Farm Stage 2	Wind	Hornsdale		•		32 x 3.2	102.0
Hornsdale Wind Farm Stage 3	Wind	Hornsdale		•		35 x 3.2	109.0
SA Diesels	Diesel	Various locations				1 x 154 1 x 123.2	277.0
Non-principal power stations [2]							
Wattle Point	Wind	Wattle Point		•	2005	55x1.65	90.8
Lake Bonney	Wind	Lake Bonney		•	2005	46x1.75	80.5
Mount Millar	Wind	Mount Millar		•	2005	35x2	70.0
Cathedral Rocks	Wind	Cathedral Rocks		•	2005	33x2	66.0
Whyalla	Waste Gas	Whyalla			1941	1x60	60.0
Canunda	Wind	Lake Bonney		•	2005	23x2	46.0
Starfish Hill	Wind	Starfish Hill		•	2003	23x1.5	34.5

Power station	Primary fuel type	Location	Cogeneration	Renewable	Year of commissioning	Unit details	Total capacity (MW)
Total of fossil fuel stations with capacity less than 10 MW [3]							**35.8**
Total of renewable stations with capacity less than 10 MW [4]				•			**26.0**

Notes:

GT: Gas Turbine; ST: Steam Turbine

1. Generating plant classified as market scheduled, market semi-scheduled, non-market scheduled or non-market semi-scheduled by the Australian Energy Market Operator (AEMO).

2. Generating plant classified as market non-scheduled or non-market scheduled by AEMO.

3. Includes non-principal fossil fuel stations with individual plant capacity less than 10 MW.

4. Includes non-principal renewable stations with individual plant capacity less than 10 MW.

Sources: Appendix 1, Australian Energy Council (2017), AEMO (2018)

The national requirement for increased volumes of both large scale and small scale renewable electricity generation under the Renewable Energy Target increases until 2020 and is stable thereafter to 2030. This ongoing policy support is expected to result in further deployment of large-scale renewable power plants and this is reflected in the number of proposed new large scale power plants and expansions (see Table 3) at various stages of development in South Australia. For small scale plants, AEMO estimates an additional 300 MW of rooftop solar PV capacity under their neutral scenario over the next five years (AEMO, 2017a).

Table 3: South Australia proposed new power stations and expansions as at March 2018

Power Station Name	Total capacity listed (MW)[3]	Plant type	Primary fuel type	Location	Status	Proposed commissioning year
Aurora Solar Energy Project	110	Solar Thermal + storage	Solar	Port Augusta	Proposed	-
Barker Inlet	210	Reciprocating engines	Natural gas/diesel	Torrens Island	Under construction	Sep-2019
Barn Hill	186	Wind turbine	Wind	Red Hill	Proposed	-
Bungala Solar Power Project	220	Solar Photovoltaic	Solar	North east of Port Augusta	Under construction	Aug-2018
Carmody's Hill	140	Wind turbine	Wind	East of Georgetown	Proposed	-
Ceres Project	636	Wind turbine	Wind	South West of Adrossan	Approved	
Dalrymple Battery storage	30	Battery storage	Storage	Yorke Peninsula	Under construction	May-2018
Elliston 1	100	Wind turbine	Wind	South of Elliston	Approved	-
Elliston 2	220	Wind turbine	Wind	South of Elliston	Approved	-
Exmoor	144	Wind turbine	Wind	Exmoor	Proposed	-
Green Point	54	Wind turbine	Wind	Green Point	Approved	-
Highbury Pumped Hydro	300	Pumped Hydro	Water	North east of Adelaide	Proposed	-
Keyneton	105	Wind turbine	Wind	South-east of Angaston	Approved	-
Kingfisher Solar Storage Project	100	Solar Photovoltaic	Solar	Roxby Downs	Approved	2017
Kongorong	120	Wind turbine	Wind	South west of Mt Gambier	Proposed	Jun-2020
Kulpara	100	Wind turbine	Wind	Kulpara	Proposed	Mar-2022
Leigh Creek Project	600	Gas turbine	Natural gas	Leigh Creek	Proposed	-
Lincoln Gap	177	Wind turbine	Wind	Lincoln Gap	Under construction	Oct-2018
Palmer	375	Wind turbine	Wind	East of Adelaide	Approved	Dec-2018
Port Augusta Renewable Energy Park	175	Solar Photovoltaic	Solar	Port Augusta	Approved	Dec-2019
Port Augusta Renewable Energy Park	206.5	Wind turbine	Wind	Port Augusta	Approved	Dec-2019
Port Augusta Solar	110	Solar thermal + storage	Solar	Port Augusta	Proposed	-

Power Station Name	Total capacity listed (MW)[3]	Plant type	Primary fuel type	Location	Status	Proposed commissioning year
Riverland solar storage	330	Solar Photovoltaic	Solar	Morgan	Proposed	-
Spencer Gulf Pumped Storage Hydro	100-200	Pumped Storage	Water	Spencer Gulf	Proposed	Dec-2020
Stony Gap	105	Wind turbine	Wind	North of Adelaide	Approved	-
Tailem Bend - Diesel	28	Compression Reciprocating Engine	Diesel	Tailem Bend	Proposed	-
Tailem Bend - Solar	100	Solar Photovoltaic	Solar	Tailem Bend	Proposed	-
Torrens Island C	700	Gas turbine	Natural gas	Torrens Island	On hold	-
Waterloo 2	20	Wind turbine	Wind	Near the Clare Valley	Completed	Nov-2016
Whyalla Solar Farm	100	Solar Photovoltaic	Solar	Whyalla	Proposed	-
Whyalla Solar Farm	140	Solar Photovoltaic	Solar	Whyalla	Proposed	Apr-2019
Willogoleche Hill	125	Wind turbine	Wind	Near Hallett	Under construction	Winter 2018
Woakwine	450	Wind turbine	Wind	East of Robe	Approved	-
Yorke Peninsula Wind Farm	636	Wind turbine	Wind	South of Ardrossan	Proposed	Jul-2020
Yorke Peninsula Biomass	15	Steam	Biomass	South of Ardrossan	Proposed	Jul-2019

Notes:

1. This table represents projects over 10MW capacity.

2. Total capacity (MW) represents maximum proposed capacity.

Sources: Appendix 2a, Australian Energy Council (2017), AEMO (2018)

1.2.1 Reliability constraints to high shares of variable renewable electricity generation

Research by CSIRO[1] indicates that the share of variable renewable electricity generation (such as wind and solar photovoltaic sources) cannot continue to increase above 40 to 50% and maintain reliable electricity supply without also expanding the capacity of other flexible generation sources such as storage and peaking natural gas plant[2]. This is a relevant technical constraint for South Australia given that its renewable generation is from variable sources and its share of renewable generation is within this range and rising (we discuss the precise renewable electricity generation share in detail in the next section).

However, we observe that the South Australian government has taken steps to support the deployment of flexible generation sources, directly investing in battery storage capacity (100 MW/129 MWh) at the Hornsdale wind farm and purchasing around 300 MW of gas turbine capacity, both deployed in 2017. The government also entered an arrangement to purchase electricity from a proposed 150 MW solar thermal plant with 8 hours storage at Port Augusta for deployment around 2020. Finally, the South Australian government has provided grants for a range of energy storage projects, including a $50 million commitment to establish the Grid Scale Storage Fund to facilitate the development of new storage technologies capable of addressing the intermittency of South Australia's electricity system.

In addition to state programs, it is also relevant that the Energy Security Board has proposed a national policy that would require retailers to purchase a minimum amount of reliable electricity generation capacity, with the amount that needs to be purchased regularly updated and determined by AEMO (ESB, 2018). This would essentially create a flexible capacity market in additional to the energy market of the NEM. This concept remains at the proposal stage. Note, that the Western Australian electricity market currently includes an explicit capacity market in addition to an energy market which is a significant point of difference to the NEM in which South Australia's electricity sector operates.

While the future ongoing South Australian or national approach to addressing the delivery of flexible generation capacity to support high variable renewable electricity generation is not settled, past direct investments by the South Australian government and the current focus of the ESB on creating a private market for future investments suggests this constraint to higher renewable share may be overcome. Another measure to improve resiliency that is part of the SA Government's energy plan includes funding to facilitate a new interconnector between South Australia and New South Wales.

[1] See, pages 115-117 of the *Low Emission Technology Roadmap* by Campey et al (2017) for a more detailed discussion.

[2] Demand management can also assist with managing this issue.

1.2.2 Distribution hosting capacity constraints to increasing rooftop solar PV generation

Distribution system voltage must be maintained within a given range to ensure that appliances connected to the system are not damaged. To help support this requirement, all rooftop solar PV systems have automated systems in their inverters which switch the solar system off if it detects that voltage at the distribution system connection has risen too high.

Generation from rooftop solar PV can be curtailed due to limited distribution system hosting capacity. That is, the distribution system can only accept rooftop solar PV exports if it is able to move that power to other parts of the network without causing a voltage increase which would exceed the tolerance of the rooftop solar inverters and switch them off.

- Knowledge about this problem is not yet at a stage where we can say exactly how much rooftop solar PV can be hosted in any given part of the distribution network. What is known is: The problem arises in residential areas with high rooftop solar PV adoption
- The curtailment is likely to occur in the middle of that day when solar output is highest and is most extreme in Summer when rooftop solar PV systems are generating at their highest level for the year
- There are regions of the South Australian network where there is more solar PV generation than customers in that area can consume as a whole
- Forecasts from AEMO indicate that South Australia as a whole may reach a point where it cannot consume all of the available rooftop solar PV generation for a few hours per year.

The solutions to this issue include both network and non-network solutions. Network solutions focus on being better prepared to move electricity around the network sometimes referred to as "two-way power flow" which represents a break from the previous paradigm where electricity was expected to move in one direction towards the customer. SA Power Networks have also placed a limit on the maximum capacity of rooftop solar PV that can be installed (5 kW for single phase residential connections[3]).

A key non-network solution is for more customers to integrate battery storage into their rooftop solar PV systems reducing solar exports. Integrated battery and rooftop solar PV systems are becoming more popular with sales increasing from approximately 6500 in 2016 to 20,800 in 2017.[4] The SA Government's intention to provide a means-tested grant averaging $2,500 to facilitate the installation of batteries in 40,000 homes will assist in this regard.

There has also been interest from retailer and new energy service companies in paying customers with residential battery systems to provide demand management services to the upstream large scale generation sector. The SA Government's intention to provide $20 million in funding customer demand response and aggregation trials will assist in facilitating the development of this market.

[3] https://www.sapowernetworks.com.au/centric/customers/solar_and_embedded_generation.jsp

[4] http://www.sunwiz.com.au/index.php/2012-06-26-00-47-40/73-newsletter/434-australian-battery-market-trebles-in-2018.html

Overall, our conclusion is that distribution hosting capacity is a relevant constraint to the growth of rooftop solar PV generation. However, this is a relatively new problem and we cannot conclude at this stage how significant this issue will be as the solutions are still under development.

1.2.3 Trends in fugitive, manufacturing and waste greenhouse gas emissions

Fugitive, manufacturing and waste emissions are largely subject to past, present and future activities levels in those industries. For example, fugitive emissions are mostly proportional to the extraction, transportation and consumption of natural gas and manufacturing emissions to the output of the manufacturing industries. Both industries can be expected to introduce improvements which may lead to reductions in emission intensity of output as they update equipment and processes. However, industrial equipment tends to be long lived and so the rate of improvement can be slow. Emissions for these two sectors have been stable in the last five years.

Emissions from landfill and waste are subject to trends in household consumption, waste separation and recycling. The emissions wastewater treatment and discharge are influenced by methane recovery and recycling rates and alternative waste treatment options. Changes in estimates for wastewater treatment and discharge emissions are largely driven by changes in industry production, population loads on centralised treatment systems and the amount of methane recovered for combustion or flaring. These are subject to decisions at local government and water utility levels which have not been reviewed.

1.2.4 Transport

It was mentioned in Section 1 that GHG emissions from the transport sector have experienced moderate growth in recent years. Similar to other states and territories, the majority of transport GHG emissions are from road transport which is dominated by petrol fuelled vehicles in the light vehicle segment (motorcycles, passenger cars and light commercial vehicles) and diesel fuelled vehicles in the heavy vehicle segments (buses, rigid trucks and articulated vehicles) in the road transport task.

In the near-term it is unlikely to see significant change in the current trend for transport sector GHG emissions due to the relatively slow turnover of the vehicle stock and the design of cities and freight networks.

GHG emissions from passenger road travel in the near-term (next five years) may be reduced by a number of means:

- Substitution of car trips by walking and cycling
- Reduced work related car trips from increased use of telecommuting or video conferencing
- Increased use of car pooling to meet the passenger travel demand with fewer vehicle kilometres travelled
- Modal shift from private car transport to public transport (buses and rail)
- Use of price signals to reduce road traffic congestion (and therefore reduce fuel consumption)

- Accelerated fleet turnover to reduce the average fuel consumption of vehicle kilometres travelled
- Increased availability of and consumer preference shift towards more efficient vehicles, including hybrids and electric vehicles.

In the near-term, GHG emissions from heavy vehicle road travel (particularly freight) may be reduced by a number of means:

- Modal shift from road to rail freight
- Maximising the load of freight vehicles through improved planning and logistics
- Greater proportion of tonne kilometres travelled by larger trucks (e.g. B-doubles compared to semi-trailers)
- Use of price signals to reduce road traffic congestion (and therefore reduce fuel consumption)
- Accelerated fleet turnover to reduce the average fuel consumption of vehicle kilometres travelled
- Increased availability of and corporate preference shift towards more efficient vehicles, including hybrids and electric vehicles.

1.2.5 Revisions in the LULUCF inventory time series

It was noted in Section 1 that the Department of the Environment and Energy (DoEE) annually revises the State and Territory Greenhouse Gas Inventories (STGGIs). The DoEE updates emission factors and methodologies when new information or more accurate methodologies become available and revises figures back to 1990 to ensure time series consistency. This re-calculation process is an obligation under the United Nations Framework Convention on Climate Change (UNFCCC).

For this reason, historical GHG emissions data may change, mainly through the re-calculation of LULUCF emissions. As the calculation of progress to the GHG target is based on the reduction (in percentage terms) to the baseline (1990 levels), any future revision to the baseline may impact the progress to target.

1.3 Review of calculation of electricity sector emissions

Greenhouse gas emissions from the electricity sector in South Australia are calculated using two different sources – the Australian Energy Market Operator (AEMO) and the State and Territory Greenhouse Gas Inventories (STGGI).

The electricity sector GHG emissions for South Australia calculated by AEMO (2016) are made up of:

- Thermal efficiencies and emission factors for each generation unit, as published in August 2016, which are used to calculate state based emissions.

- State-based emissions are determined using actual annual generation for South Australian power stations, and then added to interconnector emissions.
- Interconnector emissions are calculated using:
    - Net annual interconnector imports into South Australia.
    - Average emissions intensity of all NEM-based emissions (based on actual annual generation from all NEM power stations excluding those in South Australia).
    - An assumption that the emissions intensity of generation exported to South Australia is the same as the NEM-wide average excluding South Australia.

The STGGI uses a more aggregated approach calculating the GHG emissions from the combustion of each type of fuel in the generation of electricity in SA applying scope 1 National Greenhouse Accounts factors (DoEE, 2017b). Interconnector emissions are calculated as the "scope 2 emissions associated with the consumption of purchased electricity imported from other States and Territories net of scope 2 emissions associated with the export of purchased electricity to other States and Territories" (DoEE 2017a, p. 50). However, to reduce volatility, scope 2 emission factors are calculated as a three-year moving average. Accordingly, electricity sector GHG emissions differ slightly due to the different methodologies.

2 Renewable Energy Target

2.1 Current progress

In 2009, an additional target was made by the Minister under Part 2 of the Act stating "33.3% of South Australia's electricity generation to come from renewable energy by 2020." This superseded the previous target of 20% renewable electricity generation by 31 December 2014, which was achieved in 2011/12.

Based on data compiled by the Energy Markets group in the Department of Premier and Cabinet (DPC), the proportion of renewable electricity generation has increased significantly over recent years (Table 4).

Table 4: SA electricity generation, 2010-2017

	2010	2011	2012	2013	2014	2015	2016	2017
SA electricity generation (total) GWh	13,907	14,116	13,322	13,066	12,507	12,388	12,482	11,078
SA electricity generation (renewables) GWh	2,615	3,106	3,970	4,116	4,915	5,228	5,367	5,417
SA electricity generation (non-renewables) GWh	11,292	11,010	9,352	8,950	7,592	7,160	7,115	5,661
Proportion of renewable electricity generation	**18.8%**	**22.0%**	**29.8%**	**31.5%**	**39.3%**	**42.2%**	**43.0%**	**48.9%**

Source: DPC

The generation data shows that the proportion of SA electricity generation that was generated using renewables in 2016-17 was 48.9%. It also shows that the target of 33.3% renewable electricity generation by 2020 was achieved in 2013/14.

It is possible some factors could cause a reduction in the proportion of renewable electricity generation generated in a single year. These include:

- Increased generation from the existing fleet of non-renewable generation plant
- Reduced output of renewable electricity generation plant due to reduced wind and solar resource availability (i.e. changes in weather in a particular year)
- Increased investment and operation of non-renewable generation plant that exceeds investment and operation of renewable generation plant.

One factor that could cause a reduction in the current proportion of renewable electricity generation (other things being equal) is increased generation from the existing fleet of non-renewable generation plant. Annual generation output from non-renewable power plants varies due to a number of factors including fuel availability, scheduled maintenance, unplanned outages, transmission congestion, and market conditions.

Table 5 shows the historical generation of non-renewable plants that are still operational in South Australia for the last five years.

Table 5: Historical generation from South Australian non-renewable power stations that are currently operational (GWh), 2013-2017

Generator name	Fuel type	2012–13	2013–14	2014–15	2015–16	2016–17
Angaston Power Station	Diesel	-	-	-	0.91	7.46
Dry Creek Power Station	Gas	6.79	2.96	4.95	6.34	9.82
Hallett GT Power Station	Gas	59	34	22	33	46
Ladbroke Grove Power Station	Gas	92	232	186	206	212
Lonsdale Power Station	Diesel	-	-	-	0.62	4.55
Mintaro Power Station	Gas	13	8.21	7.33	13	31
Osborne Power Station	Gas	1,365	1,471	1,461	1,221	967
Pelican Point Power Station	Gas	2,967	1,837	1,012	293	1,183
Port Lincoln Power Station	Diesel	1.39	0.81	0.39	0.5	2.23
Port Stanvac Power Station	Diesel	-	-	-	0.95	9.5
Quarantine Power Station	Gas	150	239	216	137	265
Snuggery Power Station	Diesel	0.31	0.09	0.43	1	3.24
Torrens Island A Power Station	Gas	447	340	201	659	604
Torrens Island B PowerStation	Gas	1,697	1,403	1,488	1,969	2,278
Total		**6,798**	**5,568**	**4,599**	**4,541**	**5,623**

Note:

* Dashes (-) in the table indicate that the generator was not registered with AEMO in that financial year.

Source: AEMO (2017b)

The recent uptick (2017) in non-renewable electricity generation is mainly due to return of service of a generating unit at the Pelican Point Power Station, although most of the other power stations show an increase.

Annual generation output from renewable power plants can vary for the same reasons as non-renewable generators. For large-scale wind farms and solar PV plants, variations in resource ("fuel") availability of wind speed and solar irradiance affect output. Annual output variation of existing wind farms in South Australia (Table 6) can be represented by their capacity factor. Over the last five years, there has been variation in capacity factors that would to some degree reflect variations in renewable resource availability. The occurrence of relatively poor wind resource availability in the near-term would cause a reduction in the proportion of renewable electricity generation (other things being equal).

Another factor that could cause a reduction in the current proportion of renewable electricity generation is increased investment in non-renewable generation plant that exceeds investment in renewable generation plant (adjusted for capacity factor), other things being equal. However, based on current proposals (see Table 3) regarding new renewable power plants (around 5700 MW) compared to non-renewable generation projects (around 1500 MW) and given that a number of the renewable projects are under construction, this factor is unlikely to decrease the proportion of renewable generation in the near-term.

Table 6: Capacity factors of South Australian wind farms, 2013-2017

Wind farm	2012–13	2013–14	2014–15	2015–16	2016–17
Canunda	28.2%	31.0%	29.3%	27.9%	27.9%
Cathedral Rocks	30.3%	34.0%	29.4%	29.1%	26.1%
Clements Gap	33.4%	36.0%	33.8%	34.6%	31.7%
Hallett 1 (Brown Hill)	40.1%	42.2%	37.2%	37.8%	33.6%
Hallett 2 (Hallett Hill)	41.0%	40.9%	37.3%	38.7%	34.9%
Hallett 4 (North Brown Hill)	36.7%	40.8%	36.2%	38.3%	33.1%
Hallett 5 (The Bluff)	33.8%	36.4%	29.6%	32.6%	26.6%
Lake Bonney	27.0%	29.2%	27.2%	25.8%	25.7%
Lake Bonney Stage 2	27.2%	29.7%	28.4%	27.4%	27.5%
Lake Bonney Stage 3	27.8%	29.0%	27.4%	27.1%	27.9%
Mount Millar	30.2%	33.3%	30.5%	29.8%	26.2%
Snowtown	43.1%	44.7%	38.4%	39.2%	34.9%
Snowtown Stage 2*		52.5%	34.9%	37.0%	34.2%
Starfish Hill	22.6%	31.3%	28.4%	28.5%	19.8%
Waterloo	32.0%	34.8%	30.1%	30.7%	28.2%
Wattle Point	31.2%	37.0%	33.3%	33.8%	29.3%

Note:

* Snowtown Stage 2 capacity factor is calculated for Snowtown Stage 2 North and Snowtown Stage 2 South wind farms combined.

Source: AEMO (2017a)

Part II Revisions of Targets

3 Greenhouse Gas Emissions Targets

3.1 State and Territory targets

In October 2016, the Paris Climate Change Agreement was ratified. The main aim of the "Paris Agreement" is to limit global average temperature rise this century to well below 2^{o}C and to pursue efforts to limit the temperature increase even further to 1.5^{o}C above pre-industrial levels. In anticipation of this global agreement, The SA Climate Change Strategy (2015) included the following policy commitments in regard to GHG emissions reduction: the goal of a Carbon Neutral Adelaide; and the goal of state-wide net zero emissions by 2050.

Other states and territories in Australia have also responded setting aspirational goals for net zero GHG emissions by 2050 (Table 7).

Table 7: State/territory net zero GHG emission targets

Jurisdiction	Net Zero Target Year	Interim Targets	Legislative status	Review Process	Limits on offsets	Independent expert advice	Accountability	Transparency
Australian Capital Territory	2045[1]	2020 Target: 40% reduction on 1990 levels	*Climate Change and Greenhouse Gas Reduction Act 2010*	Independent report about GHG emissions and progress to target every year Review of Act after 5th and 10th years of operation	No limits specified in Act	Climate Change Council	Minister for Climate Change and Sustainability	The Minister must present the report to Legislative Assembly within 21 days of receipt
New South Wales	2050	To be informed by periodic Strategic Plans (e.g., Strategic Plan for 2022-27)	Not legislated (NSW Climate Change Policy Framework)	Policy framework review in 2020	N/A	Independent evaluation of Climate Change Fund programs at three-year intervals NSW Climate Change Council advise on strategic priorities	Minister for the Environment	Annual report detailing fund allocations and programs
Queensland	2050	2030 Target: 30% reduction on 2005 levels	Not legislated (Queensland Climate Transition Strategy)	Progress review in 2019 to identify a broader policy framework for Queensland's post-2020 action.	N/A	Queensland Climate Advisory Council	Minister for Environment and Heritage Protection	N/A
South Australia	2050	N/A	Not legislated (*Climate Change and Greenhouse Emissions Reduction Act 2007* legislates 60% below 1990 levels by 2050)	Minister is required, on a two-yearly basis, to prepare a report on the operation of the Act	Yes (emission offset programs must be within South Australia)	Premier's Climate Change Council Periodic review by CSIRO	Minister for Climate Change and Water	Two-yearly reports
Tasmania	2050	N/A	Not legislated (the *Climate Change (State Action) Act 2008* legislates 60% below 1990 levels by 2050)	Independent review on a four-yearly basis	No limits specified in Act	Tasmanian Climate Action Council	Minister for Environment	Tasmanian Climate Action Council report every year Four-yearly Independent review reports

Jurisdiction	Net Zero Target Year	Interim Targets	Legislative status	Review Process	Limits on offsets	Independent expert advice	Accountability	Transparency
Victoria	2050	2020: 15-20% reduction on 2005 levels. 5-yearly interim targets 2025 onwards to be set	*Climate Change Act 2017*	Report on achievement of each interim target within 2 years after the end of the interim target period	No (any forestry, carbon sequestration or soil carbon rights in Victoria or outside Victoria can be eligible offsets)	Yes (at discretion of the Minister)	Premier Minister for Energy, Environment and Climate Change	Climate Science Report (five-yearly) Annual GHG emissions report End of interim target period report

1. The revised target of 2045, compared to the legislated target of 2050, was announced the Minister for Climate Change and Sustainability.

Similar to South Australia, New South Wales and Queensland have set strategies to support the goal of net zero emissions by 2050 through their Climate Change Policy Framework and Climate Transition Strategy, respectively. Tasmania, which currently has a similar legislated target to South Australia, has released a *Climate Action 21* strategy and proposes to legislate a net zero target under the *Climate Change (State Action) Act 2008*. Western Australia and the Northern Territory do not currently have a stated GHG emissions reduction target.

In regard to legislated net zero GHG emissions targets, the Australian Capital Territory amended its *Climate Change and Greenhouse Gas Reduction Act 2010*[5], revising the long-term target from an 80% reduction on 1990 levels to a net zero GHG emissions target by 30 June 2050. This is soon to be amended to 30 June 2045.[6] The interim target of a 40% reduction on 1990 levels by 30 June 2020 has been retained. Under the Act, the Minster may determine additional interim targets. In meeting the interim and long-term target, there are no limits on eligible offsets specified in the Act.

In Victoria, the *Climate Change Act 2017*[7] (which repealed and re-enacted with amendments the *Climate Change Act 2010*) came into effect on 1 November 2017. The legislation:

- established a long-term reduction target to net zero GHG emissions by 2050
- requires five yearly interim targets, to track towards the long-term target
- introduces a new set of policy objectives and an updated set of guiding principles to embed climate change in government decision making
- requires the Government to develop a climate change strategy every five years, which will set out how Victoria will meet its targets and adapt to the impacts of climate change (from 2020)
- requires Adaption Action Plans for key systems that are either vulnerable to the impacts of climate change or essential to ensure Victoria is prepared (from 2021)
- establishes a pledging model to reduce emissions from the Government's own operations and from across the economy (from 2020)
- establishes a system of periodic reporting to provide transparency, accountability and ensure the community remains informed
- requires the Minister to obtain independent expert advice but does not establish a prescribed independent advisory body.

[5] http://www.legislation.act.gov.au/a/2010-41/current/pdf/2010-41.pdf

[6] https://www.environment.act.gov.au/home/latest_news/nations-climate-action-capital-sets-world-leading-environmental-targets

[7] http://www.legislation.vic.gov.au/Domino/Web_Notes/LDMS/PubStatbook.nsf/f932b66241ecf1b7ca256e92000e23be/05736C89E5B8C7C0CA2580D50006FF95/$FILE/17-005aa%20authorised.pdf

Under the *Climate Change Act 2017*, net zero GHG emissions means zero GHG emissions after:

(a) determining the amount of total GHG emissions attributable to the State, including any removals of GHG emissions from the atmosphere due to activities within the State; and

(b) deducting from the amount described in paragraph (a) any eligible offsets from outside of the State.

The interim emissions reduction targets must be expressed as the extent to which the amount of the State's GHG emissions is to be reduced compared to GHG emissions in 2005. The first two five-year interim reduction targets: 1 January 2021 to 31 December 2025 and 1 January 2026 to 31 December 2030; must be set on or before 21 March 2020, with subsequent interim reduction targets set eight years in advance.[8]

3.2 International targets

Similar to South Australia, following the ratification of the "Paris Agreement", a number of international jurisdictions (other nations) have proposed net zero GHG emissions targets although few jurisdictions have legislated them (Table 8).

Table 8: Net zero GHG emission targets in other nations

Jurisdiction	Net Zero Target Year	Interim Targets	Legislative status	Current status
Denmark	2050 (implied)	2020: 20% reduction on 2005 levels 2030: 40% reduction on 1990 levels	Not legislated (interim targets part of EU NDC)	Government policy set in 2015 that Denmark is to be independent of fossil fuels by 2050 (implies net zero is achievable)
New Zealand	2050	2030: 30% reduction on 2005 levels 2050: 50% reduction on 1990 levels	Not legislated (interim targets part of NDC)	Zero Carbon Bill to be introduced after consultation in 2018
Norway	2030	2020: 30% reduction on 1990 levels 2030: 40% reduction on 1990 levels	Not legislated (interim targets part of EU NDC)	Norwegian government currently working on a new climate change act
Sweden	2045	2030: 40% reduction on 1990 levels	*Climate Act*	*Climate Act* came into effect on 1 January 2018
United Kingdom	N/A	2020: at least 26% reduction on 1990 levels 2050: at least 80% reduction on 1990 levels	Not legislated (*Climate Change Act 2008*)	UK Government has announced intention to extend the Act to a net zero long-term target to align with the Paris Agreement Most recent carbon budget (2028-2032) set at 57% reduction on 1990 levels

[8] In relation to the start of each five-year period.

3.2.1 Denmark

The Danish government has ambitious national targets: meeting 50% of Denmark's energy demand by renewable energy in 2030 and becoming independent of fossil fuels by 2050 (IEA, 2017a). The interim target towards its long-term goals align with the nationally determined contribution (NDC) of the European Union (EU): 40% reduction on 1990 levels by 2030.

The EU's NDC is an economy-wide GHG emission reduction goal and is defined as a domestic target (no offsets outside the EU). However, compared to the previous pledge of the EU, the 2030 target includes emissions/removals LULUCF, which were not included in the 2020 target under the Kyoto Protocol.

The accounting rules for the LULUCF calculation are yet to be agreed. In July 2016, the European Commission presented a proposal for a regulation that provided member states with some flexibility concerning the accounting of emissions from the LULUCF and allowed using credits for emissions reduction in the LULUCF sector in the non-ETS sectors (European Commission, 2016). After the European Parliament (European Parliament, 2017) and the Council (Council of the European Union, 2017) adopted separate positions, the final version of the proposal will be discussed in inter-institutional negotiations. The proposed flexibility in transferring emissions reduction between the LULUCF and other sectors poses a threat that would significantly weaken the EU's emissions reduction target for 2030.[9]

3.2.2 New Zealand

In December 2017, the New Zealand government announced its intention to legislate a Zero Carbon Act.[10] Cabinet agreed to a process of consultation during 2018, before the Zero Carbon Bill is introduced to parliament.

As part of the Paris Agreement, New Zealand has committed to a target to reduce GHG emissions 30% below 2005 levels by 2030. Prior to Zero Carbon Act announcement, it had a stated long-term goal to reduce GHG emissions 50% below 1990 levels by 2050 (New Zealand Government, 2015).

A recent report by the Parliamentary Commissioner for the Environment (2018) highlighted some of the challenges and trade-offs that will need to be considered in developing a Zero Carbon Act based on a UK style Climate Act, that accounts for New Zealand's particular circumstances (preference for market-based instruments and large share of agriculture sector in GHG emissions).

3.2.3 Norway

In June 2016, Norway's Parliament approved a national goal to achieve climate neutrality by 2030, accelerating the initial 2050 target. The Parliament approved a resolution to achieve climate neutrality "through the EU emissions trading market, international cooperation on emissions reductions, emissions trading and project-based cooperation".

[9] http://climateactiontracker.org/countries/eu.html

[10] https://www.mfe.govt.nz/news-events/zero-carbon-act

Norway signed and ratified the Paris Agreement on 20 June 2016. Norway's nationally determined contribution (NDC) includes a target of reducing GHG emissions by "at least 40%" below 1990 levels in 2030, aligning itself with the European Union's target. The inclusion of emissions and removals from the LULUCF sector was made dependent on the EU's approach to this issue.

Although the base year for Norway's NDC is set with respect to GHG emissions excluding LULUCF in 1990, Norway intends to use the land-use, land-use change and forestry sector to achieve its emissions reduction. The NDC submission states that the 40% reduction commitment includes additional measures in the land sector, but the 'final choice of land sector accounting shall not affect the ambition level for 2030." It is therefore unclear whether the NDC will exclude or include additional measures in the land sector.[11]

The Norwegian government is currently working on a new climate change act that will legislate GHG emissions reduction targets. The parliament has asked the government to legislate a target for 2050 that states a low-emission society has emissions levels of 80-95% below 1990 levels (IEA, 2017b).

3.2.4 Sweden

In June 2017, the Swedish Parliament (Riksdag) passed the *Climate Act* to take effect from 1 January 2018 (Governmental Proposition 2016/17:146[12]). It commits Sweden to net zero GHG emissions by 2045 (after emission offsets) with a goal of domestic emissions at least 85% lower than 1990 levels. In addition to domestic reductions, net zero can be achieved by (i) GHG emission reductions abroad, (ii) bio-energy with carbon capture and storage (BECCS), and (iii) increased carbon dioxide uptake in land use, land-use change and forestry (LULUCF). These measures are in place to substitute for emissions with no recognised reduction alternatives, such as GHGs from agriculture and some industrial processes, which are estimated to account for around 15% of GHGs (Krook-Riekkola and Sandberg, 2018).

The emissions in Sweden that will be covered by the EU's segregation of regulation, the so-called the Effort Sharing Regulation (ESR)-sector[13], should at least be 63 per cent lower than 1990 emissions by 2030. Not more than 8 percentage points of emission reductions may be made by supplementary measures. These measures include, for example, increased uptake of carbon in the soil and forest, the capture and storage of biogenic carbon dioxide or mitigation actions in other countries.

By 2040, GHG emissions in Sweden in the ESR-sector should be at least 75 per cent lower than 1990 levels. Not more than 2 percentage points of the emissions reductions may be made by supplementary measures. In addition, GHG emissions from domestic transport (except domestic aviation included in the EU's emissions trading system, the EU ETS) should be reduced by at least 70 per cent below 2010 levels by 2030.

Emissions from national aviation are not included in the intermediate objectives for 2030 and 2040 (when part of the EU emission trading system). Supplementary measures for intermediate

[11] http://climateactiontracker.org/countries/norway.html

[12] Governmental Proposition 2016/17:146. Ett klimatpolitiskt ramverk för Sverige (In Swedish)

[13] These include transport, buildings (mainly heating), agriculture, waste management and small-scale industry.

targets can for example be increased uptake of carbon dioxide by forests or by investing in various climate projects abroad.

3.2.5 United Kingdom

The *Climate Change Act 2008*[14] introduced the world's first long-term legally binding framework to reduce GHG emissions in the United Kingdom. The main mechanism is the setting of five-yearly carbon budgets. The 2050 target (at least 80% reduction on 1990 levels) and the 2020 interim target (at least 26% reduction on 1990 levels) are the only targets stated in the Act. Carbon budgets, in contrast, are set by Ministerial order.

The final emissions total which must fall below the Act's targets and carbon budgets is the "net UK carbon account", which is the UK's net emissions less any carbon units from emissions trading schemes, including international schemes. However, under the Act, the Secretary of State for Climate Change must set limits on how many units can be credited in this manner, after taking into account the advice of the Committee on Climate Change (CCC) – an independent body under the Act. For the most recent carbon budget (2018-2022), carbon units are limited to 2% of the carbon budget despite the CCC recommending a zero limit (CCC, 2016a).

In March 2016, the UK Government announced its intention to extend the Act to a net zero long-term target, in alignment with the Paris Agreement. This was endorsed by the CCC, but it recommended focus on short-term action while developing a strong evidence-based net zero emissions strategy (CCC, 2016b).

[14] https://www.legislation.gov.uk/ukpga/2008/27/contents

4 Renewable energy target

The South Australian Climate Change Strategy (2015) included the following policy commitments in regard to renewable energy: the goal of 50% renewable energy generation by 2025.

The AEMO (2017c, p.4), recently reported that:

- By 2020-21 approximately 73% of generation in South Australia is projected to be produced by renewable sources, increasing from approximately 49% of total region generation in 2016-17
- By 2026-27 the generation produced by renewable sources is projected to increase to approximately 75% to 80% in South Australia, depending on the renewable pathway. The increase in renewable generation is expected to reduce gas-powered generation (GPG) down from approximately 50% in 2016-17 to 20-25% of regional generation in 2026-27.

The projections (Table 9) are based on analysis conducted using the Neutral demand scenario and the *Dispersed* and *Concentrated renewables pathways* for the 2017 *Electricity Statement of Opportunities* (ESOO) for the National Electricity Market (NEM). These renewable development pathways present two possible futures, considered reasonable given incentives to expand renewable generation currently provided within the market by supportive state and federal renewable energy targets.

Table 9: Forecast annual energy supply mix for South Australia (GWh)

	South Australia generation						Interconnector flows		
	Wind (SS , NS)	SNSG	Rooftop PV	Solar (SS)	Scheduled (S)	Total generation	Imports (Victoria to South Australia)	Exports (South Australia to Victoria)	Net interchange (positive = imports, negative = exports)
2016–17 (actual)	4,343	95	1,016	0	5,623	11,077	2,889	164	2,725
Neutral economic growth scenario - Concentrated renewables pathway									
2017–18	5,898	106	1,181	0	6,400	13,585	1,243	997	246
2018–19	5,979	111	1,282	411	5,601	13,383	1,371	1,029	342
2019–20	7,246	126	1,393	972	4,503	14,240	1,520	1,483	37
2020–21	7,367	134	1,508	1,097	3,756	13,863	1,978	1,514	464
2021–22	7,361	141	1,623	1,084	3,447	13,656	2,322	1,576	746
2022–23	7,456	151	1,724	1,060	3,644	14,035	2,137	1,707	431
2023–24	7,513	159	1,848	1,044	3,504	14,068	2,221	1,743	478
2024–25	7,295	166	1,972	1,026	3,529	13,988	2,323	1,682	641
2025–26	7,254	175	2,092	1,007	3,605	14,134	2,301	1,699	602
2026–27	7,249	183	2,212	993	3,598	14,235	2,327	1,717	611
Neutral economic growth scenario - Dispersed renewables pathway									
2017–18	5,898	106	1,181	0	6,401	13,586	1,242	997	245
2018–19	5,979	111	1,282	411	5,601	13,383	1,371	1,029	342
2019–20	7,246	126	1,393	972	4,503	14,240	1,520	1,483	37
2020–21	7,368	134	1,508	1,097	3,737	13,843	2,003	1,518	486
2021–22	7,498	141	1,623	1,166	3,419	13,847	2,200	1,650	550
2022–23	7,859	151	1,724	1,290	3,507	14,531	1,890	1,956	-66

	South Australia generation						Interconnector flows		
	Wind (SS , NS)	SNSG	Rooftop PV	Solar (SS)	Scheduled (S)	Total generation	Imports (Victoria to South Australia)	Exports (South Australia to Victoria)	Net interchange (positive = imports, negative = exports)
2023–24	8,175	159	1,848	1,407	3,277	14,865	1,857	2,171	-315
2024–25	8,119	166	1,972	1,487	3,233	14,977	1,875	2,215	-340
2025–26	8,249	175	2,092	1,554	3,238	15,309	1,782	2,344	-562
2026–27	8,481	183	2,212	1,617	3,158	15,651	1,723	2,511	-788

Notes: SS stands for Semi-scheduled, NS for Non-scheduled, S for Scheduled, and SNSG for small non-scheduled generation (SNSG are non-scheduled generating units typically less than 30 MW including small rooftop PV non-scheduled power generation (PVNSG) and other small non-scheduled power plants (ONSG)).

Rooftop PV estimates are based on the 2017 NEM ESOO forecasts.

Source: Table 1, AEMO (2017c)

It can be observed from Table 9 that net imports may remain volatile but under the *Dispersed Renewables Pathway*, with more large-scale renewable generation becoming available in South Australia, the region could become a net exporter from 2022–23 onwards.

Previous reviews of tracking the renewable energy target have highlighted the complexity of calculating a consumption share of renewables, including the difficulty of identifying renewable energy content in imports. Given this complexity and it appears likely that net imports will be modest for the next several years, for the immediate future, reporting against the objective of renewable energy generation should continue to be calculated without reference to consumptions, exports or imports.

In light of the expected outlook for renewable generation in SA, and if it becomes more certain that SA will be established as a net exporter in the NEM in most years and that net export position will be growing, it is proposed that the issue of an alternative measure should be revisited in future years. For example, some consideration could be given to returning to the concept of a consumption share rather than generation share of renewable energy. If exports become a large proportion of generation, generation share reporting could begin to overstate the contribution of renewable electricity generation in the share of electricity consumed in SA.

Appendix A

Table 10: SA greenhouse gas emissions by source and sink category (levels and change), Kyoto Protocol since 1990

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Energy	21,025	19,438	20,685	20,639	20,529	20,667	19,780	20,377	21,451	21,911	22,269	22,512	22,913	23,729
Industrial Processes	2,774	2,658	3,217	3,181	3,176	3,156	3,075	3,104	3,238	3,171	3,176	3,142	3,159	3,186
Agriculture	6,484	6,329	6,221	6,221	6,042	5,816	5,846	5,770	5,940	5,943	5,952	5,954	6,188	6,040
LULUCF	1,630	238	- 1,008	- 2,189	- 1,150	- 2,947	- 1,772	- 507	- 1,125	- 2,662	- 1,207	- 1,628	269	- 1,081
Waste	1,389	1,386	1,219	1,238	1,054	1,244	968	915	774	802	766	784	863	831
Total incl. LULUCF	33,302	30,049	30,334	29,090	29,651	27,936	27,897	29,659	30,279	29,165	30,957	30,765	33,392	32,705
Change since 1990		-9.8%	-8.9%	-12.6%	-11.0%	-16.1%	-16.2%	-10.9%	-9.1%	-12.4%	-7.0%	-7.6%	0.3%	-1.8%

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Energy	23,649	23,997	23,592	24,537	24,880	23,539	23,504	21,961	21,215	20,213	19,881	19,728	19,914
Industrial Processes	3,189	3,000	3,017	3,255	3,209	3,232	3,377	3,381	3,764	3,805	3,548	3,656	3,720
Agriculture	6,081	5,865	5,747	5,589	5,077	5,192	4,942	5,723	5,620	5,637	5,803	5,588	5,519
LULUCF	- 1,076	- 353	159	- 1,882	- 3,204	- 2,431	- 3,192	- 5,111	- 2,629	- 2,924	- 2,214	- 2,378	- 3,806
Waste	797	755	779	794	880	891	890	899	881	935	953	866	1,072
Total incl. LULUCF	32,639	33,264	33,294	32,293	30,842	30,423	29,521	26,852	28,851	27,666	27,972	27,460	26,419
Change since 1990	-2.0%	-0.1%	0.0%	-3.0%	-7.4%	-8.6%	-11.4%	-19.4%	-13.4%	-16.9%	-16.0%	-17.5%	-20.7%

Source: Australian Greenhouse Emissions Inventory System (AGEIS) http://ageis.climatechange.gov.au [accessed 2 May 2018]

Table 11: SA greenhouse gas emissions by source and sink category (levels and change), UNFCCC since 1990

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Energy	21,025	19,438	20,685	20,639	20,529	20,667	19,780	20,377	21,451	21,911	22,269	22,512	22,913	23,729
Industrial Processes	2,774	2,658	3,217	3,181	3,176	3,156	3,075	3,104	3,238	3,171	3,176	3,142	3,159	3,186
Agriculture	6,484	6,329	6,221	6,221	6,042	5,816	5,846	5,770	5,940	5,943	5,952	5,954	6,188	6,040
LULUCF	1,276	- 232	- 1,660	- 2,799	- 1,547	- 3,332	- 2,288	- 629	- 1,306	- 2,672	- 1,208	- 1,443	137	- 958
Waste	1,389	1,386	1,219	1,238	1,054	1,244	968	915	774	802	766	784	863	831
Total incl. LULUCF	32,948	29,579	29,682	28,479	29,254	27,550	27,381	29,537	30,097	29,155	30,955	30,950	33,261	32,828
Change since 1990		-10.2%	-9.9%	-13.6%	-11.2%	-16.4%	-16.9%	-10.4%	-8.7%	-11.5%	-6.0%	-6.1%	1.0%	-0.4%

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Energy	23,649	23,997	23,592	24,537	24,880	23,539	23,504	21,961	21,215	20,213	19,881	19,728	19,914
Industrial Processes	3,189	3,000	3,017	3,255	3,209	3,232	3,377	3,381	3,764	3,805	3,548	3,656	3,708
Agriculture	6,081	5,865	5,747	5,589	5,077	5,192	4,942	5,716	5,609	5,637	5,803	5,588	5,519
LULUCF	- 835	208	1,058	- 850	- 2,522	- 2,086	- 2,933	- 5,379	- 2,789	- 2,969	- 1,978	- 2,407	- 3,879
Waste	797	755	779	794	880	891	890	816	784	935	953	866	1,072
Total incl. LULUCF	32,879	33,824	34,193	33,325	31,524	30,768	29,780	26,495	28,583	27,621	28,208	27,430	26,334
Change since 1990	-0.2%	2.7%	3.8%	1.1%	-4.3%	-6.6%	-9.6%	-19.6%	-13.2%	-16.2%	-14.4%	-16.7%	-20.0%

Source: DoEE (2018b)

Shortened forms

Abbreviation	Meaning
AGEIS	Australian Greenhouse Emissions Inventory System
AEMO	Australian Energy Market Operator
BECCS	Bio-Energy with Carbon Capture and Storage
CCC	Committee on Climate Change
CO_2-e	Carbon-dioxide equivalent
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DoEE	Department of the Environment and Energy
DPC	Department of Premier and Cabinet
ESB	Energy Security Board
ESOO	Electricity Statement of Opportunities
ESR	Effort Sharing Regulation
ETS	Emissions Trading Scheme
EU	European Union
Gg	Gigagrams
GHG	Greenhouse gas
GPG	Gas-powered generation
GT	Gas Turbine
GWh	Gigawatt-hour
IEA	International Energy Agency
kW	Kilowatt
LULUCF	Land use, land use change, and forestry
MW	Megawatt
MWh	Megawatt-hour
NDC	Nationally Determined Contribution
NEM	National Electricity Market
NS	Non-Scheduled
p.a.	per annum
PV	Photovoltaic
SA	South Australia
SNSG	Small Non-Scheduled Generation
SS	Semi-Scheduled
ST	Steam Turbine
STGGI	State and Territory Greenhouse Gas Inventory
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change

References

Australian Energy Council (2017) *Electricity Gas Australia*, AEC.

AEMO (2016) *South Australian Historical Market Information Report*. Australian Energy Market Operator. August, http://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/SA_Advisory/2016/2016_SAHMIR.pdf

AEMO (2017a) *South Australian Renewable Energy Report*. Australian Energy Market Operator. November, http://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/SA_Advisory/2017/South-Australian-Renewable-Energy-Report-2017.pdf

AEMO (2017b) *South Australian Historical Market Information Report*. Australian Energy Market Operator. September, http://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/SA_Advisory/2017/South-Australian-Historical-Market-Information-Report-2017.pdf

AEMO (2017c) *South Australian Generation Forecasts.* Australian Energy Market Operator. December, https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/SA_Advisory/2017/2017-South-Australian-Generation-Forecast.pdf

AEMO (2018) Regional Generation Information Page: South Australia, update 16 March 2018, Australian Energy Market Operator, http://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Generation_Information/March-2018/Generation_Information_SA_March_2018.xlsx

Campey, T., Bruce, S., Yankos, T., Hayward, J., Graham, P., Reedman, L., Brinsmead, T., Deverell, J. (2017) *Low Emissions Technology Roadmap*. CSIRO, Australia. Report No. EP167885, https://www.csiro.au/~/media/EF/Files/LowEmissionsTechnologyRoadmap-Main-report-170601.pdf

CCC (2016a) Lord Deben, Chair of the Committee on Climate Change "Letter: Use of offset credits to meet the third carbon budget (2018–2022)", 24 February, http://www.theccc.org.uk/wp-content/uploads/2016/02/Letter-use-of-offset-credits-to-meet-the-third-carbon-budget.pdf

CCC (2016b) *UK climate action following the Paris Agreement*, October, https://www.theccc.org.uk/wp-content/uploads/2016/10/UK-climate-action-following-the-Paris-Agreement-Committee-on-Climate-Change-October-2016.pdf

Council of the European Union (2017) "Proposal for a Regulation of the European Parliament and of the Council on the Inclusion of Greenhouse Gas Emissions and Removals from Land Use, Land Use Change and Forestry into the 2030 Climate and Energy Framework and Amending Regulation No 525/2013 of." http://data.consilium.europa.eu/doc/document/ST-13249-2017-INIT/en/pdf

DoEE (2017a) *State and Territory Greenhouse Gas Inventories: Australia's National Greenhouse Accounts*. Department of the Environment and Energy, May, http://www.environment.gov.au/system/files/resources/15d47b77-dee2-42c6-bf2e-6d73e661f99a/files/state-inventory-2015.pdf

DoEE (2017b) *National Greenhouse Accounts Factors: Australia's National Greenhouse Accounts*. Department of the Environment and Energy, July, http://www.environment.gov.au/system/files/resources/5a169bfb-f417-4b00-9b70-6ba328ea8671/files/national-greenhouse-accounts-factors-july-2017.pdf

DoEE (2018a) *National Inventory Report 2016: 3 volumes*. Department of the Environment and Energy, April, http://www.environment.gov.au/climate-change/climate-science-data/greenhouse-gas-measurement/publications/national-inventory-report-2016

DoEE (2018b) *State and Territory Greenhouse Gas Inventories 2016: Australia's National Greenhouse Accounts*. Department of the Environment and Energy, February, http://www.environment.gov.au/system/files/resources/a97b89a6-d103-4355-8044-3b1123e8bab6/files/state-territory-inventories-2016.pdf

DoEE (2018b) *National Inventory Report 2016: Volume 2*. Department of the Environment and Energy, April, http://www.environment.gov.au/system/files/resources/02bcfbd1-38b2-4e7c-88bd-b2b7624051da/files/national-inventory-report-2016-volume-2.pdf

ESB (2018) *National Energy Guarantee: draft design consultation paper*. Energy Security Board, February, http://www.coagenergycouncil.gov.au/sites/prod.energycouncil/files/publications/documents/Energy%20Security%20Board%20National%20Energy%20Guarantee%20-Consultation%20Paper_0.pdf

European Commission (2016) "Proposal for a Regulation of the European Parliament and of the Council on the Inclusion of Greenhouse Gas Emissions and Removals from Land Use, Land Use Change and Forestry into the 2030 Climate and Energy Framework and Amending Regulation No 525/2013 of." http://eur-lex.europa.eu/resource.html?uri=cellar:9901f171-5017-11e6-89bd-01aa75ed71a1.0001.02/DOC_1&format=PDF

European Parliament (2017) "Inclusion of Greenhouse Gas Emissions and Removals from Land Use, Land Use Change and Forestry into the 2030 Climate and Energy Framework." http://www.europarl.europa.eu/sides/getDoc.do?type=TA&language=EN&reference=P8-TA-2017-0339

IEA (2017a) *Energy Policies of IEA Countries: Denmark 2017 Review*. International Energy Agency: Paris. http://www.iea.org/publications/freepublications/publication/EnergyPoliciesofIEACountriesDenmark2017Review.pdf

IEA (2017b) *Energy Policies of IEA Countries: Norway 2017 Review*. International Energy Agency: Paris.

Krook-Riekkola, A. and Sandberg, E. (2018) "Net-zero CO2 emission pathways for Sweden by cost-efficient use of forestry residues," in Giannakidis G., K. Karlsson, M. Labriet, B. Ó Gallachóir (eds.) *Limiting Global Warming to Well Below 2°C: Energy System Modelling and Policy*

Development. Springer, Lecture Notes in Energy, pp. 123-136, https://link.springer.com/book/10.1007/978-3-319-74424-7

New Zealand Government (2015) *New Zealand Submission to the ADP: New Zealand's Intended Nationally Determined Contribution*, 7 July 2015, http://www4.unfccc.int/submissions/INDC/Published%20Documents/New%20Zealand/1/New%20Zealand%20INDC%202015.pdf

Parliamentary Commissioner for the Environment (2018) *A Zero Carbon Act for New Zealand: Revisiting Stepping stones to Paris and beyond*, March, http://www.pce.parliament.nz/media/196427/zero-carbon-act-for-nz-web.pdf

CONTACT US

t 1300 363 400
+61 3 9545 2176
e csiroenquiries@csiro.au
w www.csiro.au

AT CSIRO, WE DO THE EXTRAORDINARY EVERY DAY

We innovate for tomorrow and help improve today – for our customers, all Australians and the world.

Our innovations contribute billions of dollars to the Australian economy every year. As the largest patent holder in the nation, our vast wealth of intellectual property has led to more than 150 spin-off companies.

With more than 5,000 experts and a burning desire to get things done, we are Australia's catalyst for innovation.

CSIRO. WE IMAGINE. WE COLLABORATE. WE INNOVATE.

FOR FURTHER INFORMATION

Energy
Luke Reedman
t +61 2 4960 6057
e luke.reedman@csiro.au
w www.csiro.au/energy

Energy
Paul Graham
t +61 2 4060 6061
e paul.graham@csiro.au
w www.csiro.au/energy