Solar PV & wind offer by far the best chance to avoid dangerous climate change

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Summary

- Australia is installing renewable energy (solar photovoltaics (PV) and wind) 4-5 times faster per capita than the EU, USA, Japan and China.
- The electricity sector is on track to deliver Australia's entire Paris emissions reduction targets several years early provided that substantially more transmission and storage is constructed
- Remarkably, the net cost is zero because expensive fossil fuels are being replaced by cheaper renewables.
- Stabilising the electricity grid when it has 50-100% renewable energy is straightforward using off-the-shelf techniques including transmission and storage
- Australia is on track for deep and rapid greenhouse emissions reductions through deep renewable electrification. Much of the world can readily follow the Australian path. Renewable energy offers real hope for a future liveable planet.

The requirement for rapid and deep emissions cuts

- The cost of electricity from PV & wind is below that from new build coal and gas generators. PV & wind will soon be competitive with the operational cost (fuel & maintenance) of existing black coal power stations, leading to a wave of retirements and rapidly reducing emissions from coal
- PV & wind technology is running far faster than energy & greenhouse policy.
- **The key requirement for continued rapid deployment of new PV and wind is facilitation of adequate storage and transmission.**
- Essentially, a very effective Australian greenhouse policy boils down to **facilitation of adequate storage and transmission.**

Rapidly declining greenhouse emissions

The electricity sector is on track to deliver Australia's entire Paris emissions reduction targets several years early as explained below. Remarkably, the net cost is zero because expensive fossil fuels are being replaced by cheaper renewables.

Substitution of renewable electricity for gas and coal reduces greenhouse emissions. Each additional GW of renewables reduces emissions from coal power stations by about 2 Megatonnes (MT). This assumes capacity factors of 15%, 21% and 40% for roof-mounted PV, ground-mounted PV and wind respectively, curtailment losses of 4%, and greenhouse emissions from black coal power stations of 0.9 tonnes per MWh. The current renewables pipeline of 5-7 GW per year causes net emissions reduction of 10-12 MT each year.

Total Australian emissions have been increasing, substantially due to increased liquified natural gas (LNG) exports. This increase is moderating because of stabilisation of emissions from LNG.

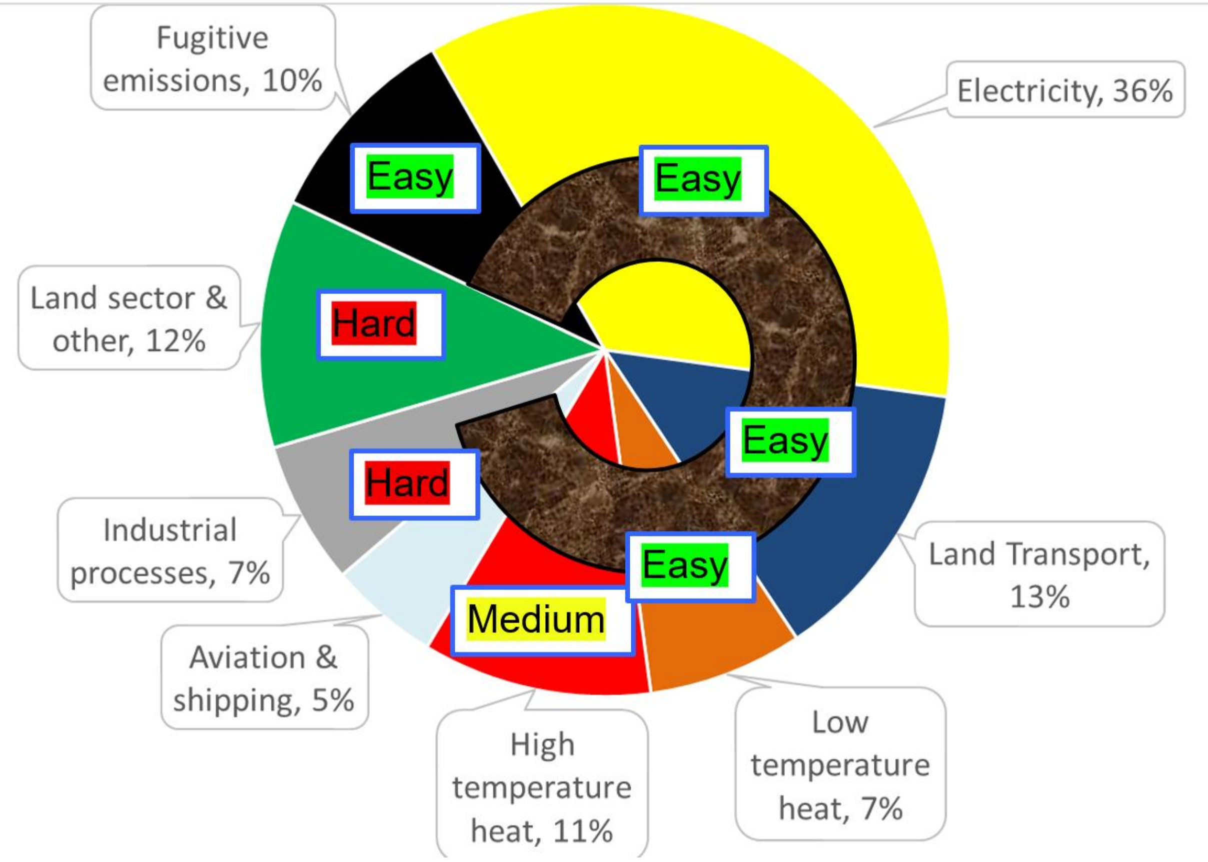
From mid-2018 there was a large increase in deployment rate of PV and wind. The effect of this is gradually flowing through into 12-monthl moving-averages of greenhouse emissions.

Future increases in emissions outside the electricity system are likely to be smaller than decreases in the electricity sector from the uptake of wind and PV, leading to an overall decrease in emissions provided that current PV & wind deployment rates continue. This decrease could be fast enough to reach Australia's entire Paris target in the mid-2020s.

In the medium term, large reductions in emissions are likely using off-the-shelf technology through elimination of coal and gas from the electricity sector (36%), gas from the heating sector (18%) and oil from land transport (13%). Looking further ahead, curtailment of fossil fuel mining and exports would remove a further 10% of emissions. Deep renewable electrification of the remaining economic sectors, including electro-chemicals (synthesised from electric-driven water splitting and atmospheric carbon-capture), allows elimination of all oil, gas and coal, causing an 85% reduction in greenhouse gas emissions. Eliminating land clearing and ecological restoration can eliminate most of the rest.

Electrification of land transport and heating requires a doubling of electricity production. Driving all fossil fuels out of the economy requires a tripling of electricity production.

If Australia keeps installing PV and wind at the current rate, then all fossil fuel use would be eliminated around 2050. Importantly, the continuing rapid decline in the cost of PV and wind and increasing renewable electricity demand arising from the elimination of gas heating and the rise of electric vehicles leads to accelerated deployment of PV and wind during the 2020s, and a much earlier end-date for fossil fuels.



Australian emissions pie chart. The brown broken circle represents emissions from oil, gas and coal, amounting to ~80% of the total. Conversion of electricity to renewables is well underway and reduces emissions by one third. Widespread renewable electrification of land transport (via electric vehicles) and urban heating (via heat pumps) is likely in the 2020s and reduces emissions by up to 20%. PV & wind are already marginally competitive for industrial heating (via electric furnaces) and can displace gas in the mid-2020s. Fugitive emissions will decline in proportion to the mining of coal and gas for domestic consumption & export. Thus, most emissions can be avoided by renewable electrification using off-the-shelf technology.

Rapid renewable energy deployment

Australia is installing renewable energy 4-5 times faster per capita than the EU, Japan, China and the USA.

Australia is experiencing a remarkable renewable energy transition. The pipeline for new wind and solar photovoltaic (PV) electricity systems is 6-7 Gigawatts (GW) per year. This equates to 250 Watts per person per year compared with about 50 Watts per person per year for the European Union, Japan, China and the USA. This renewable energy pipeline is fast enough to reach 50% renewable electricity in 2024 and 100% in 2032.

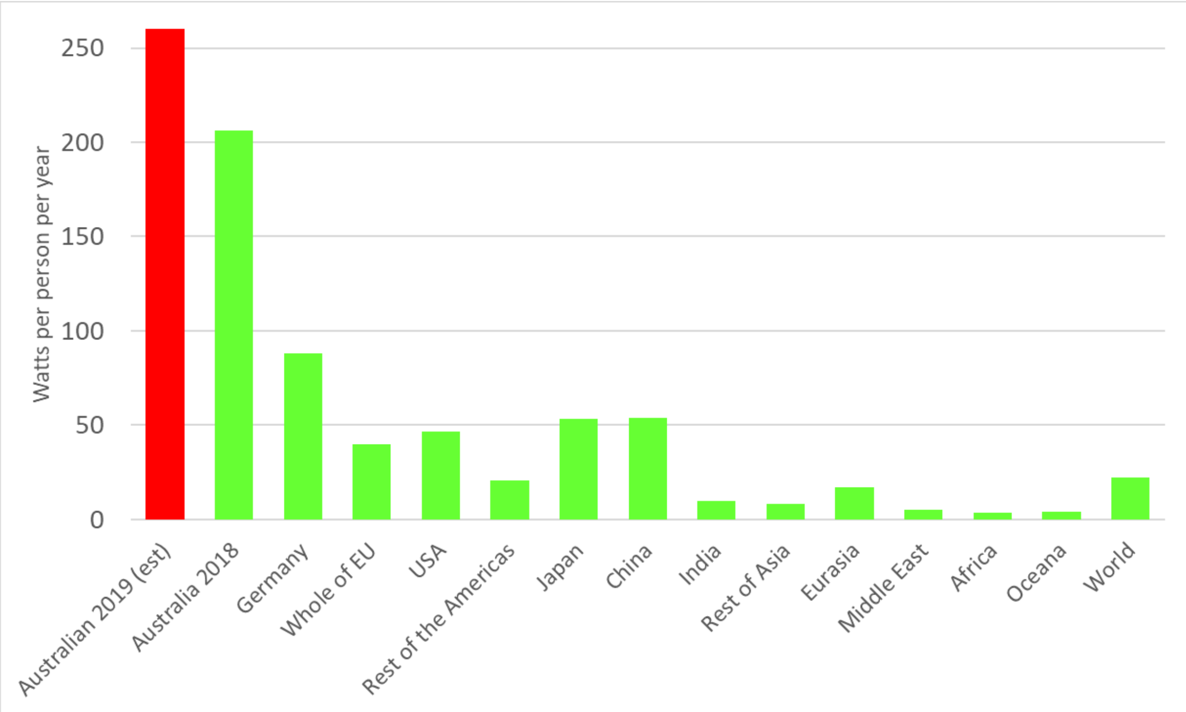


Fig. 1: Annual per capita renewables deployment rate for countries and regions. Data for Australia (2018 and 2019) is from the Clean Energy Regulator [1] and data for other countries/regions (2018) is from IRENA [2].

Global renewable energy deployment

Wind and PV constitute about 60% of global net new capacity additions

Solar PV, wind and hydro together account for two thirds of global net new capacity additions, with gas and coal comprising most of the balance [2]. China, EU, India, USA and Japan accounted for three quarters of global new renewable deployment in 2018 [2].

In 2018 Australia deployed 5.1 GW of PV and wind systems (3.5 GW ground-mounted, 1.6 GW roof-mounted). Clean Energy Regulator (CER) data [1] indicates that the current ground-mounted PV and wind pipeline for 2019 is about 4 GW. Roof-mounted PV is likely to exceed 2 GW in 2019, for a total renewable energy deployment of above 6 GW in 2019. At this rate, Australia is on track to reach 50% renewable electricity in 2024 and 100% in 2032.

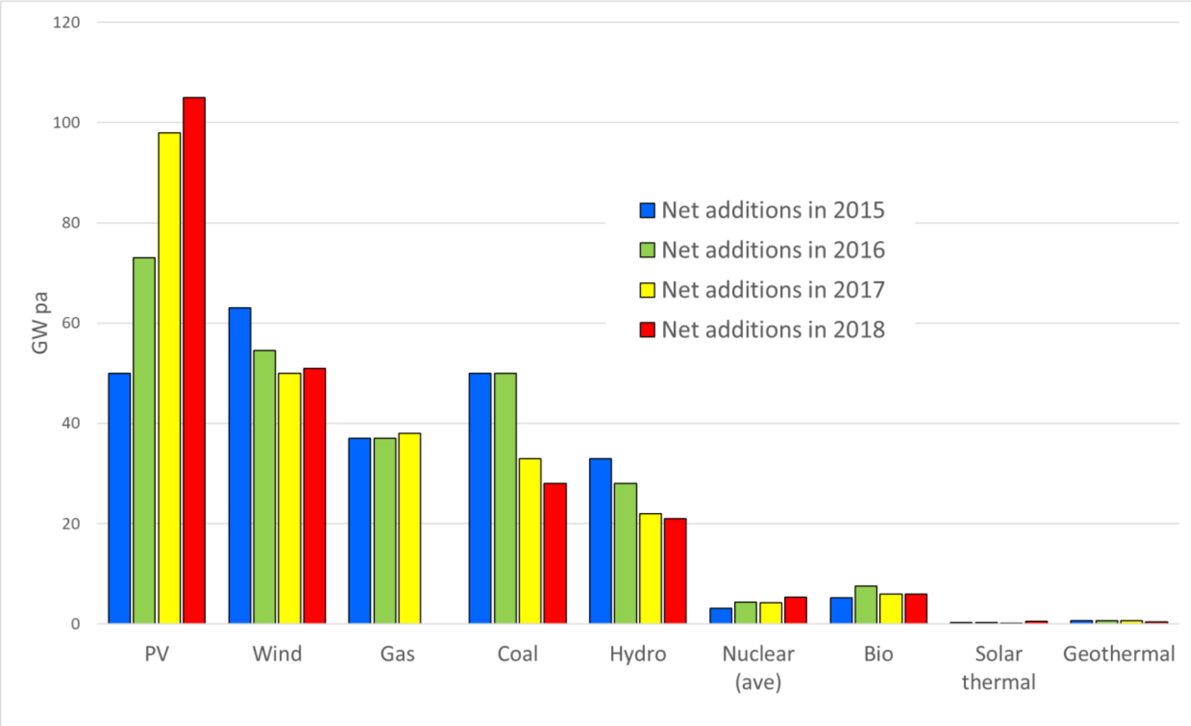


Fig. 1: Global net new capacity additions 2015-18 [2-11]

Sustainability of the Australian renewable energy pipeline

About 9 GW of roof mounted solar PV has now been deployed, which is by far the largest per capita rooftop-PV deployment in the world. Australian cities have good sunshine by world standards, and the cost of electricity from rooftop PV systems is far below the retail tariff for most home owners and businesses.

The impetus provided by the Australian Renewable Energy Target [12] allowed great industry experience and critical mass to be developed in the construction of ground-mounted PV and wind farms. The Target has now effectively been met, and new PV and wind farms can no longer expect significant subsidy support. The price of electricity from large-scale PV and windfarms in Australia is currently $50-60 per Megawatt-hour (MWh), and falling. This is below the cost of electricity from existing gas-fired power stations and is also below the cost of new-build gas and coal power stations. PV and wind comprise nearly 100% of new power stations.

The Australian renewable energy pipeline is sustainable in the long term. The average age of Australia's coal power stations is 30 years. The cost of electricity from PV and wind is already similar to the cost of fuelling and maintaining much of the black coal fleet. Premature retirement of many existing black coal power stations is likely during the 2020s, enlarging the market for PV and wind.

PV and wind are already substantially cheaper than retail gas for low temperature air and water heating in buildings, particularly when used in conjunction with an electric heat pump. Gas use in buildings is likely to decline in the 2020s. Complete displacement of gas would increase electricity demand by 8%, which would come from new-build PV and wind. Gas for use in industrial furnaces at $10 per Gigajoule has an equivalent price of about $45/MWh assuming a combustion efficiency of 80%. In the 2020s, electric furnaces using PV and wind electricity will become competitive, opening a further large market.

Electric vehicles (EV) are likely to make substantial inroads into the land transport market during the 2020s. Complete conversion of the vehicle fleet to EV would increase electricity demand by 38%, almost all of which would come from new-build PV and wind.

The wind and PV farms, pumped hydro and grid extensions will be in regional areas, bringing long term sustainable investment and jobs.

Stabilisation of the grid

Stabilising the electricity grid when it has 50-100% renewable energy is straightforward using off-the-shelf techniques that are already widely used in Australia.

The techniques comprise storage, demand management, and strong interstate interconnection using high voltage transmission lines to smooth out the effect of local weather [13]. By far the leading storage technologies are pumped hydro [14] and batteries (including EV batteries) [15]. Multi-gigawatt-scale storage and transmission projects are being actively considered by Governments and private interests. In addition, new smart energy systems are being developed for electricity grids.

ANU's global pumped hydro site atlas [18] lists 616,000 sites, with storage potential of 23 million GWh, which is 100-200 times more than needed to support a 100% global renewable electricity industry: http://re100.eng.anu.edu.au/global/index.php

The cost of hourly balancing of the Australian electricity grid is modest: about $5/MWh for a renewable energy fraction of 50%, rising to $25/MWh for 100% renewables [13, 16]. Thus, the cost of the required storage and transmission is considerably smaller than the cost of the corresponding wind and solar farms. Australia's coal power stations are old and are becoming less reliable, and transition to a modern renewable energy system can improve grid stability.

Government subsidies for PV and wind are no longer required. However, State and Federal Government facilitation of private investment into storage (such as Snowy 2.0 and other pumped hydro storage systems) and interstate transmission would be very helpful, similar to Government facilitation of new roads to remove traffic bottlenecks.

The Snowy 2.0 pumped hydro project is world-scale (2 GW capacity, 350 GWh of storage) and has commenced construction. Although it is located within a national park, almost all facilities are underground, and environmental impacts are manageable with care [17].

Renewable energy zones (REZ)

Substantial strengthening of regional grids is required to allow PV & wind electricity to be brought to cities. Development of REZ in places with good wind and sun, and good pumped hydro sites, allows the low-cost development of Gigawatt-rated transmission lines and facilitates further rapid deployment of PV & wind.

Transferability to other countries

Australia is on track for deep and rapid greenhouse emissions reductions through deep renewable electrification, at approximately zero net cost. Much of the world can readily follow the Australian path.

If developing countries follow a fossil fuel intensive pathway then very serious damage will be done to Earth's climate. On the other hand, following a renewables pathway coupled with ending land clearing decouples economic development from climate damage.

Most of the world's population lives in the sunbelt (+/- 35° of latitude). Here is also where most of the world's growth in population and energy consumption is occurring. There are no cold winters and heating loads are small. This region has ample sunshine and low seasonal variation of both demand and solar insolation. Most countries are within a few thousand kilometres of regions with excellent wind resources, which allows high voltage DC powerline connection and gives access to the frequent counter-correlation of solar and wind. There is low requirement for (expensive) seasonal storage and vast numbers of excellent sites for off-river pumped hydro storage [18].

Low-latitude countries are more like Australia rather than Europe or north America or north Asia. These countries can follow the Australian path and transition rapidly to renewables with consequent large avoidance of future greenhouse emissions.

	Sunbelt	Australia	The north
Latitude	Low	Low	High
Solar resource	High	High	Low-moderate
Seasonality of solar	Low	Low	High
Access to wind	Moderate	High	High
Heating load	Low	Low	High
Need for seasonal storage	Low	Low	High
Pumped hydro site count	High	High	High
Wealth & technology	Low-Moderate	High	High
Current fossil fuel capacity	Low	High	High

Table 1: Developing countries have good prospects for bypassing a fossil fuel era

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