Land requirement for a 100% renewable (zero carbon) economy is 1200 km^2

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Land use calculations are based on reasonable scenarios. There is no one "right answer". However, all reasonable scenarios produce the same overall result, that land requirements to support a zero fossil fuel economy are small.

In the scenario described below, where there is doubt about the best choice of a parameter, we err towards exaggerating land requirements. Exact numbers are not important compared with identifying whether land requirements are large or small. In summary, if we had zero fossil fuel use throughout the economy today, then:

- The ***area alienated*** by the renewable energy industry would be small, around 1200 km^2. The word "alienated" means that the land has little utility for other uses.
- The ***area spanned*** is about 15 times larger, but most of this is suitable for continued agriculture. The area spanned is mostly occupied by farming between wind turbine towers. It is wrong to confuse the area that is spanned with the area that is alienated.

Electricity generation triples to replace all fossil fuels

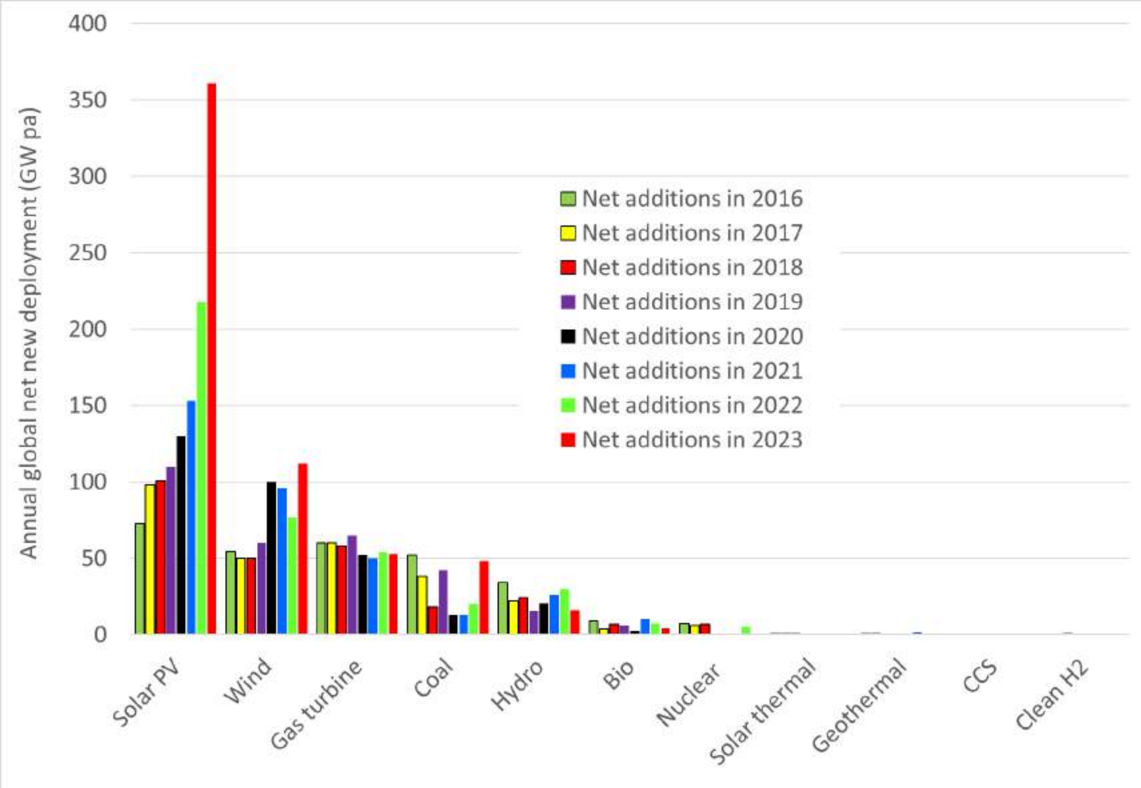
Current electricity consumption in Australia is about 10 Megawatt-hours (MWh) per capita per year (272 TWh divided by 27 million people).

"Electrification of everything" allows the removal of fossil fuels from the Australian economy, and their replacement with solar and wind. This entails electrification of land transport via electric vehicles; electrification of air and water heating via electric heat pumps; electrification of industry via electric furnaces; and production of hydrogen atoms for the chemical industry via electrolysis (ammonia, clean metals, plastics, ceramics, chemicals, synthetic aviation and shipping fuels).

When we electrify transport, heating and industry then annual electricity consumption per capita doubles. Production of synthetic aviation and shipping fuels and other materials is additional. We assume that electricity consumption must triple for complete decarbonization, to 30 MWh per capita per year. This maximises land requirements.

Solar and wind replace fossil fuels

In 2023, solar and wind energy comprised 80% of global electricity generation capacity additions. Everything else combined (coal, gas, hydro, nuclear and other renewable) comprised the other 20%. Global solar capacity is doubling every 3 years and is tenfold larger than 10 years ago. It is obvious that solar and wind won the global energy race. We assume that solar & wind provide all the required 30 MWh of electricity per capita per year, to maximise land requirements.



Global net capacity additions 2016-23. Solar and wind are dominant. Everything else is static or small. IRENA, IEA, GEM, WNA

This renewable electricity comes from rooftop solar, solar farms and wind farms. Solar farms alienate more land than wind farms per unit of energy production. Rooftop solar alienates no land. Currently, rooftop solar dominates solar deployment. However, the area of available roof space is constrained.

The assumed fractions of production of 30 MWh of electricity per capita per year are listed below. This choice is at the high end of likely land alienation.

- Rooftop solar: 15-35% of electricity, say 25% of 30 MWh = ***7.5 MWh/year per capita***
- Solar farms: 30-60% of electricity, say 40% of 30 MWh = ***12 MWh/year per capita***
- Wind farms: 20-50% of electricity, say 35% of 30 MWh = ***10.5 MWh/year per capita***

Solar farms

Solar farms comprise many rows of solar panels that are spaced apart from one another, leaving gaps between the rows. In some solar farms the gaps are small, while in others the gaps are two panel widths, so that the panels only cover one third of the ground. In some farms, the solar panel rows rotate to track the sun, while in others the panels are fixed, usually with a tilt to the north.

We assume that the area alienated by a solar farm is equal to the shading area of the panel and supports, because sunlight does not reach the ground through the panels. However, the area spanned by a solar farm could be double or triple the panel area if the rows are spaced widely apart. The area between the panel rows is available for agriculture, such as sheep farming. The panels provide shelter from wind and sun.

According to the International Technology Roadmap for PV, solar panel efficiency in 2030 will be around 24%, which corresponds to 240 Watts of power per square metre under standard test conditions. There is also shading from supports and trackers. We assume that the power output is 200 Watts per square metre of shaded (alienated) land, which is equivalent to 5,000 m^2 per Megawatt (1 MW is one million Watts).

Most solar farms are located inland from the Great Dividing Range where there is high and consistent annual sunshine, as shown in the global solar atlas. The DC capacity factor of a single axis tracking system is about 21%, which means that a 1 MW solar farm effectively produces at full output for 21% of the 8760 hours in a year, or 1840 MWh per year. This is enough for 153 people (1840 MWh divided by 12 MWh per person). Thus, the area of land alienated per person is 5,000 m^2 divided by 153 people or 33 m^2 per person.

The typical area spanned by the solar farm is 2-3 times the area of the solar panels – around 100 m^2 per person. Most of this land need not be lost to agriculture, as shown in the picture below.

Image: Warwick Solar Farm. Clean Energy Council / University of Queensland

Wind farms

Windfarms typically comprise turbines spread over a sheep or cattle farm. A typical 4 MW turbine comprises a 100 m high tower with rotor length of 80 m. Sheep graze right up to the edge of the tower, so little land is alienated. There is about one turbine per 1 km^2.

The disturbed land amounts to less than one Hectare, comprising perhaps 0.4 Ha around the tower, and a 4 m wide access road to each turbine, plus miscellaneous areas.

According to the global wind atlas, typical annual output of a 4 MW wind turbine in rural Australia is 4 MW times 3,680 hours per year, or 14,720 MWh per year. In our scenario we assume that windfarms produce 10.5 MWh/year per capita, and so each turbine serves 14,720 divided by 10.5 equals 1400 people. Thus, the area alienated by wind farms is 1.0 Ha per 1400 people or 7 m^2 per person.

The area spanned by the windfarm is about 100 times the area alienated – around 700 m^2 per person. This land is not lost to agriculture, as shown in the picture below.

Image: Steve Meese/Shutterstock

Putting it together

Storage (batteries and pumped hydro) is required to support the solar and wind, amounting to about 3 m^2 per person. New transmission is required to collect the energy from the solar and wind farms. The Australian Energy Market Operator estimates that 10,000 km of new transmission might be needed, amounting to about 37 centimetres per person. Transmission alienates little land since grazing and cropping continues right up to the edge of each tower. We assume that transmission and storage alienates about 5 m^2 per person

The area per person alienated by the solar farms is 33 m^2, and for the windfarms it is 7 m^2.

Thus, the total area alienated by a 100% renewable energy (zero fossil fuel) economy is about 45 m^2 per person. The current population of Australia is 27 million people. Thus, the total area of land required today is 1200 km^2. The area devoted to agriculture is about 3,500 times larger.

If the future population of Australia increases, then so will land alienation by solar and wind farms. However, the area of land that is alienated continues to be a very small fraction of agricultural land.

The area spanned by the solar and windfarms is around 800 m^2 per capita, or about 18 times larger than the area of land that is alienated. However, most of this land remains available for agriculture. It is important not to confuse the land alienated with the land spanned by solar and wind farms.