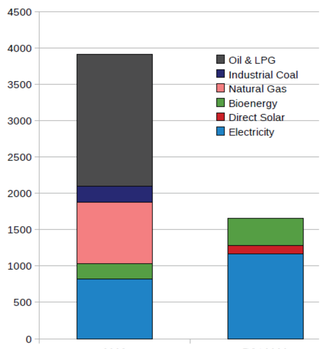
100% Renewable Energy for Australia in 10 years

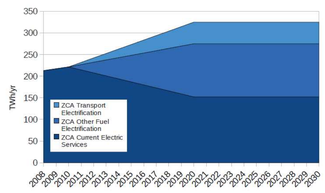
Rebecca Dunn[1], Patrick Hearps[2] and Matthew Wright [2]

Electricity demand: 325 TWh per year

Australian Energy Sources: Present and Under ZCA2020



Total electricity demand including fuel switch and transport electrification



Total delivered energy use under the plan is reduced by more than half, from 3,915 PJ/yr (2008) to 1,660 PJ/yr (2020), as shown in the graph to the left. The same level of energy services are maintained, including transport, heating, cooling, industrial energy use and so on. This is achieved by a combination of energy efficiency measures, and by switching energy services currently provided with oil and natural gas, mostly for transport and heating, with far more efficient electrical systems. For instance:

- **Internal combustion engines (20% efficient) are replaced by fast electric rail and electric cars (80-90% efficient).**
- **Space heating is switched from gas to heat pump systems. This is combined with serious retrofits of insulation in all buildings.**

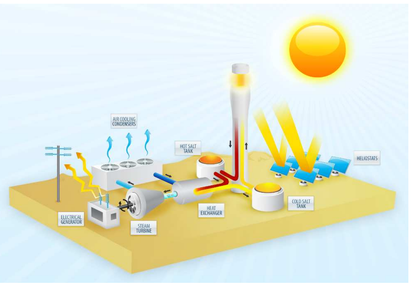
To accommodate this switch from fuel to electricity, the total electricity use increases from 228 TWh/yr to 325 TWh/yr, even though energy efficiency measures cause the energy use for current electrical services to fall, as can be seen in the graph to the left. An allowance is made for biogas and biofuels to meet energy demands that cannot be electrified.

Concentrating Solar Thermal and Wind

The Plan specifies 23 wind farm sites and 12 concentrating solar thermal (CST) sites at geographically diverse locations around Australia, but within reasonable proximity to existing grid infrastructure. In total, there are 6,400 x 7.5 MW wind turbines in the Plan – a model such as the Enercon E-126 turbine could be used. Meanwhile, an installed capacity of 3,500 MW is proposed at each CST site, all with 17 hours of storage. CST provides power on demand, similarly to a gas-fired peaker, but without the emissions from burning gas. This makes it a good complementary generating source for wind. During periods of high wind speeds, electricity from wind power is dispatched to the grid first, while the sun's energy is used mainly to heat salt for storage. Conversely, when wind speeds are low, the hot molten salt at CST plants produces extra steam for the turbines and makes up for the lull in wind generation.

How a molten salt power tower works

A sea of mirrors reflects the sun's energy towards the top of a tower. Liquid salt from the cold tank is pumped to the top of the tower where it is heated by the concentrated heat from the sun. This energy is then stored as heat in the hot salt tank. Electricity can then be produced on demand, day or night, by passing the salt through the heat exchanger to produce steam to drive a turbine and generator.



Left: Enercon E-126 turbines in a corn field in Belgium. **Right:** The operating principle of a CST power tower with molten salt storage, such as the Torresol Gemasolar plant.

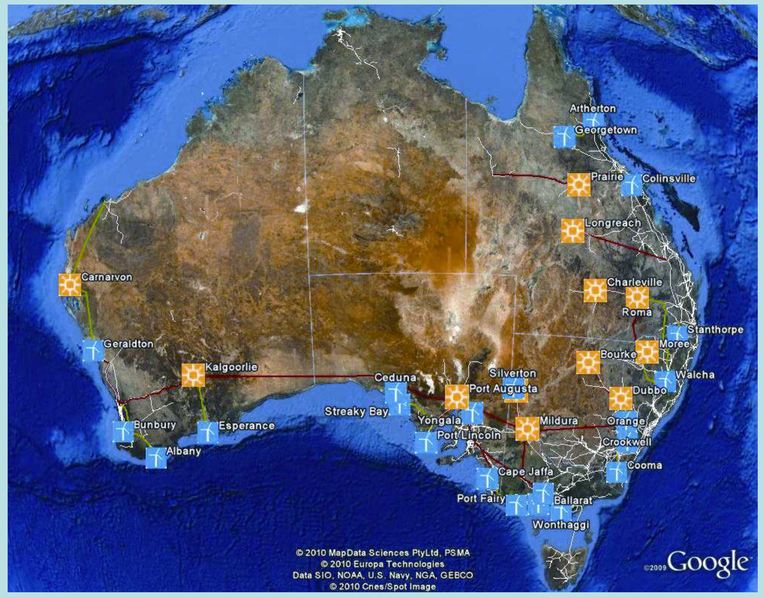
Overview

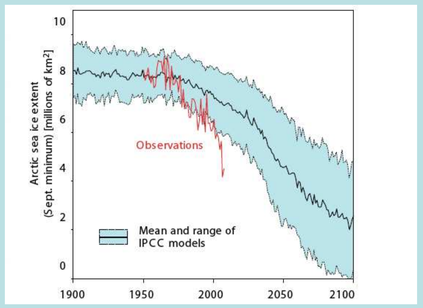
The Zero Carbon Australia 2020 Stationary Energy Plan (ZCA2020 Plan) outlines a technically feasible and economically attractive way for Australia to transition to 100% renewable energy within ten years.

As shown in the figure below, climatic tipping points such as the complete loss of summer Arctic sea ice are being approached much sooner than predicted. The German Advisory Council on Global Change states that in order to have a 67% chance of keeping global warming to less than 2°C above pre-industrial temperatures, countries with high per capita emissions such as Australia, would need to reduce emissions to zero in 10 years.

The ZCA2020 Plan shows that with a combination of energy efficiency, fuel-switching from gas and oil to electrified energy services, then using a combination of commercially available renewable energy technologies, Australia's energy needs can be met with 100% renewables. The Plan recommends the following commercially available technologies:

- **Concentrated Solar Thermal (CST) Power Towers with 17h molten salt heat storage:** meeting ~ 60% of annual electricity demand;
- **Wind power:** meeting the remaining ~ 40% of annual demand;
- **Crop-waste biomass and existing hydroelectricity:** providing backup for 2% of the annual demand, when simultaneous lulls in solar and wind cause shortfalls in supply;
- **A National Grid:** this allows geographically diverse wind and solar plants to smooth each others' outputs, and demand curves to be flattened.





Above: The ZCA2020 Australian grid, showing the locations of proposed wind and CST plants, and transmission upgrades to form a national grid (green = HVAC, red = HVDC). **Top right:** The Arctic sea ice is melting at a rate far exceeding the worst-case predictions of the IPCC. **Bottom right:** Torresol's Gemasolar plant, a 17 MW power tower with 15 hours of molten salt storage, under construction in Spain, February 2010. Here, a few hundred of the final 2,500 mirrors have been installed.

Summary

The ZCA2020 Stationary Energy Plan outlines a fully costed and detailed blueprint for transforming Australia's energy sources to a 100% renewable supply. This is achievable using technology that is commercially available today. The cost to investors is AU$37 billion dollars per year for 10 years, or approximately 3% of GDP. If this was paid back in electricity sales from 2011-2040, the extra cost to households would be only be $8 per household per week.

Constructing the proposed renewable infrastructure over a ten-year timescale would take only 7% of Australia's current concrete production and 1.3% of our iron ore exports. It would create 80,000 construction jobs, 30,000 manufacturing jobs, and 45,000 ongoing jobs in operations and maintenance – more than replacing the current 20,000 jobs in the domestic fossil energy supply sector.

The ZCA2020 Stationary Energy Plan is the first in a series of 6 reports outlining detailed transitions to zero emissions for each sector of the Australian economy: Buildings, Transport, Industrial Processes, Land Use & Agriculture, and Replacing Coal Export Revenue. These will feed into a second version of the ZCA2020 Stationary Energy Plan. Further work will include investigating the installation of pumped hydro storage at existing dams to reduce the use of biomass backup.

Rebecca Dunn was part of the research team for the *Zero Carbon Australia Stationary Energy Plan*, published by climate solutions think tank *Beyond Zero Emissions* in collaboration with the University of Melbourne. The full plan is available free online or for hard copy purchase at

www.beyondzeroemissions.org

Modelling the Renewable Energy Supply

ZCA2020 Grid Model Results for 2009 (based on daily averages)

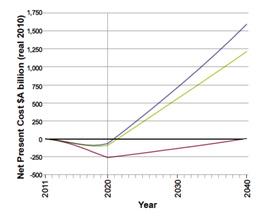
To confirm that the proposed system can meet the projected demand, modelling has been carried out on a half-hourly timescale, with solar insolation, wind speed and National Electricity Market demand data from 2008 and 2009. As seen in the 2009 modelling above, the proposed 50 GW of wind and 42.5 GW of concentrating solar thermal (CST) alone can meet 98% of the projected electricity demand.

The combination of existing hydro and biomass generation as backup at the CST sites can meet the remaining 2% of annual demand, covering the few occasions where periods of low wind and extended low solar resource coincide. It is proposed that biomass pellets from crop residue be used to heat the molten salt during these periods, avoiding duplication of turbines, generators and other equipment that already exists at the CST plants. The biomass required for such backup is equivalent to pelletising 13% of the straw residue from the annual Australian wheat crop.

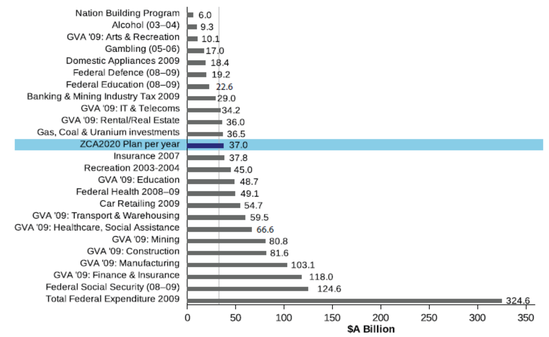
Economic Modelling

The ZCA2020 Plan requires investment of AU$37 Billion/year – the equivalent of 3% of GDP, shown for comparison against annual spending in other sectors of the economy in the graph below. The graph to the rights shows a Net Present Cost comparison of Stationary Energy spending under Business-As-Usual, compared to ZCA2020 spending. The point where the curve crosses the horizontal axis is the economic "break-even" point compared to Business-As-Usual. The purple curve represents a scenario in which only direct stationary energy costs are taken into account – under this scenario break-even occurs at 2040. However, if the avoided future cost of transport oil is also taken into account, the break-even point occurs only a year and a half after the end of the Plan implementation (green curve), and if a future carbon price is included, the break-even occurs sooner again (blue curve).

Cumulative Net Present Costs: BAU minus ZCA2020



ZCA2020 Stationary Energy Plan capital cost compared to other economic activity



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