beyond ZERO emissions

Zero Carbon Australia 2020

Stationary Energy Sector Report – Executive Summary

Australia has one of the greatest renewable energy resources in the world, which we can capitalise on to repower our economy with clean, safe and secure renewable energy. The *Zero Carbon Australia 2020 Project (ZCA2020)* is a costed, detailed blueprint outlining a ten year transition to a **zero-emissions economy**.

Incorporating only proven and commercialised technologies, requiring an estimated capital investment equivalent to only 3-3.5% of gross domestic product over ten years, the *ZCA2020 Project* outlines how Australia can transition to **100% renewable energy** production by 2020.

Abengoa's Solar Power Station in Spain © Greenpeace / Markel Redondo

100% Renewable Energy by 2020

Beyond Zero Emissions, a non-profit, independent climate change solutions research and advocacy group is currently working on the *Zero Carbon Australia 2020 Project (ZCA2020)*. *ZCA2020* is a costed, detailed blueprint for a transition to a zero-emissions economy in ten years using proven, commercialised technology.

The purpose of *ZCA2020* is to show the Australian public and decision-makers that reaching a zero emissions economy is not only desirable, but ready to be implemented and only awaits sign-off from the Australian Government. The document aims to initiate serious and urgent efforts to mitigate the risks posed by global warming, and to describe the infrastructure and resources required to reduce Australia's carbon emissions to zero in the medium term.

Climate Science Demands Urgent Action

Reliable, peer-reviewed climate science calls for a reduction in atmospheric CO2 (carbon dioxide) concentrations from today's level at almost 390 parts per million (ppm) to less than 350ppm, most likely 300ppm [1]. Incremental reductions in carbon emissions, such as the proposals for 5%-25% reductions currently on the Australian political agenda, will not achieve this target if adopted globally. Transitioning to a zero-emissions economy by 2020 represents Australia doing its bit to prevent catastrophic global warming.

The aims of *ZCA2020* are consistent with the objective of achieving a safe climate future and align with a number of international studies and campaigns including:

- The Potsdam Institute's Carbon Budget 2010-2050 (Figure 1) calls for countries with high per-capita emissions, such as Australia and the USA, to decarbonise by 2020 [2].
- Al Gore's RePower America campaign calls for 100% clean electricity powering the USA within a decade [3].
- Stanford University engineering academic Mark Z. Jacobson has recently published a plan for 100% renewable energy for the whole world by 2030 [4].

ZCA2020 Terms of Reference

ZCA2020 relies exclusively on technologies and solutions that are commercially available and that can be costed with confidence. *ZCA2020* calls for the provision of infrastructure that will allow the maintenance or improvement of Australian living standards, comfort, and personal mobility whilst achieving the necessary decarbonisation.

ZCA2020 Plan Sectors

ZCA2020 will cover stationary energy, transport, industrial processes, buildings, land use and agriculture, and replacement of coal exports. The summary of the stationary energy sector transition plan is presented in this document.

Stationary Energy

This sector includes all infrastructure that generates and distributes energy to end users and includes electricity generation plants, natural gas and oil recovery, refining and distribution. In *ZCA2020*, fossil fuel-fired electricity generation is replaced by renewable energy, principally concentrated solar thermal with storage and wind generation.

Natural gas and fossil-based liquid fuelled transport is likewise phased out and replaced by transport powered primarily by renewable-generated electricity, with a small use of biofuels in rural areas and emergency services. Elimination of these fuels causes an increase in the total national electricity demand from 211 Terawatt hours (TWh) (2007) to 325 TWh (2020) excluding off-grid generators. However, by employing greater efficiency in the use of energy generally, and by minimising the use of inefficient internal combustion engines, the total amount of energy delivered in Australia falls from 3,834 Petajoules (1,065 TWh-equivalent) in 2007 to 1,643 Petajoules (456 TWh-eq) in 2020. Figure 2 illustrates this. In the building sector for example, energy-saving measures employed in the *ZCA2020* plan include a switch to heat pump heating and extensive insulation of all commercial and residential buildings.

Overall, 60% of electricity supplied by a 100% renewable stationary energy sector will be provided by concentrating solar thermal with molten salt heat storage and 40% by wind power. Photovoltaic solar panels will also produce electricity during sunny periods, and hydroelectricity and crop residual biomass will provide back-up energy when needed. This is described further below and in full detail in the upcoming *ZCA2020 Stationary Energy Sector Report*.

Carbon budget 2010-2050

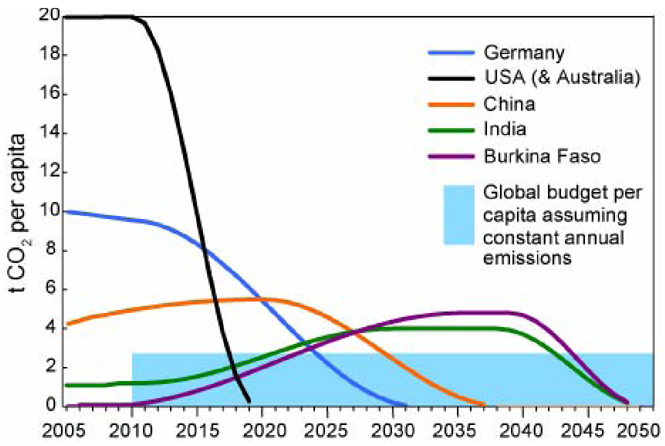

Figure 1: Emissions paths per capita for selected countries based on 2010 population (67% probability of not exceeding 2 degrees celsius)

Source: Prof Hans Joachim Schellnhuber, Director, Potsdam Institute Presentation to "4 Degrees & Beyond" International Climate Conference 28-30 September 2009, Oxford

24-hour solar electricity

Australia has the best solar resource of any developed country [5]. This is Australia's primary strategic advantage in the new zero-carbon economy. The backbone technology for Australia's 2020 electricity generation system is therefore concentrating solar thermal (CST) power-towers with molten salt heat storage, illustrated in Figure 3 below. This technology is already being installed in Spain and the USA [6] [7]. Residential and commercial photovoltaic systems (solar panels) will still be used to reduce demand on the electricity grid during sunny periods.

With a dozen geographically diverse plant sites, CST provides readily available (dispatchable) electricity 24 hours a day. These 24-hour baseload solar plants use mirrors to concentrate sunlight onto a receiver, then store the generated heat in hot molten salt at 565-650ºC. The heat stored in this molten salt is used to boil water, creating steam to drive conventional turbines, and is available day or night. When the turbine is idle, heat is taken off the "cold" 290ºC salt storage tank to keep the turbine seals warm, allowing fast starting as seen in the best hydroelectricity and gas plants, making them amongst the highest value electricity plants. This capacity for both baseload and fast-start dispatchable power generation allows CST plants to address and profit from demand peaks.

CST power-towers with molten salt heat storage are able to operate at 60 – 100% of maximum turbine output for up to 90% of the hours each year with very low maintenance shutdown requirements. Air-cooling of the power cycle reduces water requirements to less than 12% of a conventional thermal power plant (such as conventional coal plants) [9]. Australia is well-positioned to supply the requisite concrete, steel, glass and expertise for the construction of these plants across the country creating many jobs in the process.

Twelve sites around Australia have been chosen for CST installations, accounting for transmission availability and quality of resource (Figure 5 and 6 – yellow squares). Each site will have a capacity of approximately 3500 Megawatts electrical (MWe), giving a total of 42 Gigawatts electrical (GWe).

Each site installation consists of around 20 power tower modules, allowing for these to be scaled up from 50MWe in early installations to 217MWe in later models. Each CST module consists of a molten salt power tower system with steam turbine, and enough mirror field to provide thermal heat for both daytime power generation, and stored energy for night-time generation. The molten salt storage is sufficient for up to 17 hours generation at full power. A particular emphasis was placed on sites with high winter-time solar incidence, as this will be the critical system supply period. Site-by-site solar resource data is publicly available through Australia's Bureau of Meteorology and NASA [10].

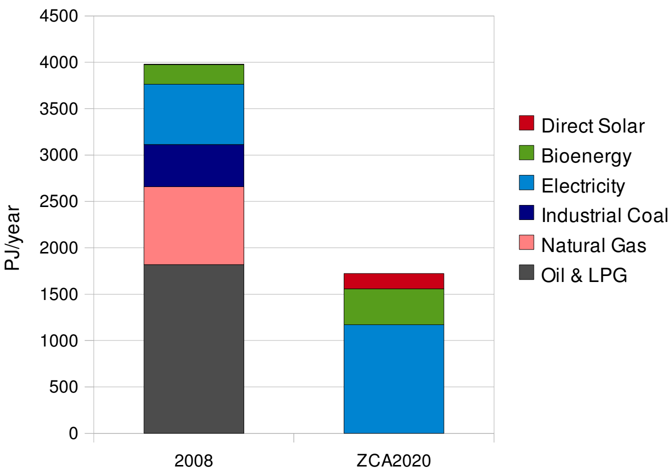

Figure 2: Australian End-Use Energy Present and ZCA2020. Efficiency & fuel-switching significantly lowers Australia's 2020 total energy demand. Note industrial coal is separate from coal used for electricity generation.

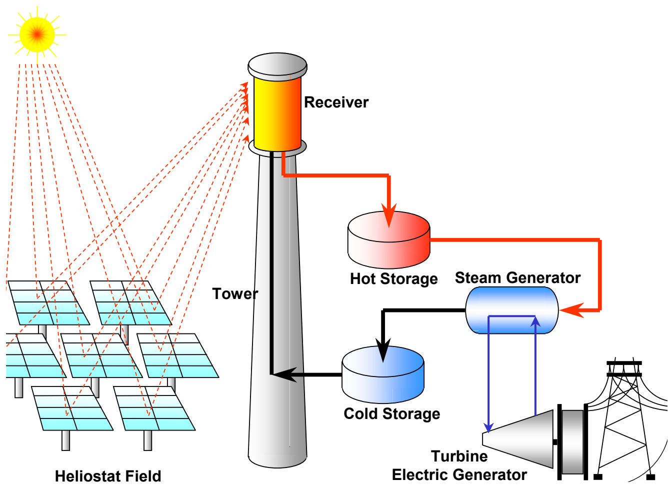

Figure 3: Diagram of a concentrated solar thermal (CST) power tower with molten salt storage [8] – in practice there are thousands of heliostats.

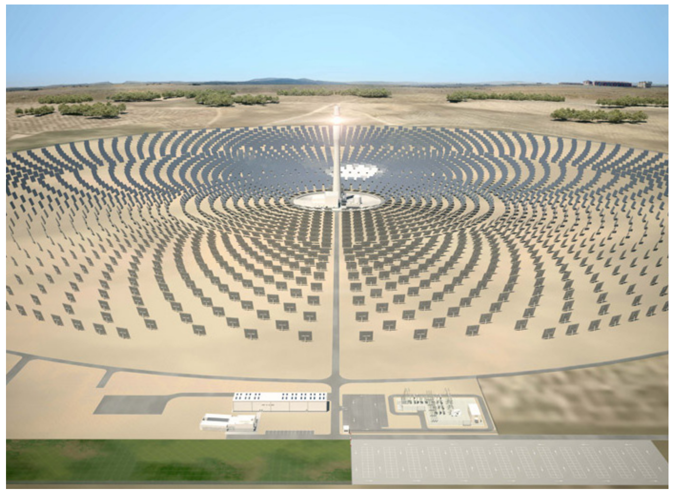

Figure 4: Computer Generated image of the Torresol Gemasolar power tower in Spain.

Twenty per cent of the nation's CST system will be installed in 4 years (from 2011 - 2014). This equates to an installed capacity of 8,700MWe, operating for an average 17 hours per day including storage to provide 55TWh/yr. This is 17% of the projected total 2020 national stationary energy demand. As production capacity increases, the remaining CST plants will be constructed from 2015-2020.

Costings of CST are based on the U.S. Department of Energy and Sargent & Lundy Consulting LLC [11] projections. Cost projections were developed through investigating industrial learning curves and the impact of economies of scale. Sargent & Lundy determined that once 8.7 GW of molten salt power tower capacity has been installed globally, solar thermal power will provide electricity at a cost competitive with conventional coal power (~ 5 cents/kWh). These are the projections *ZCA2020* has used in calculating the CST component of the transition to a zero emissions stationary energy sector, taking into account the higher costs of the first CST plants to be built.

Consistent, dispersed wind generation

World-class on-shore wind resources are Australia's second strategic advantage in renewable energy. Wind power is the cheapest of all clean energy sources available in Australia and is technologically mature. *ZCA2020* couples wind with CST with molten salt storage to provide reliable, dispatchable, lowest-cost, and emissions-free electricity. Wind power is dispatched to the grid whenever it is available, and power generated from the CST molten salt storage makes up the difference to meet demand at all times. Approximately 48GWe of installed wind turbine capacity (~ 8,000 x 6 MWe turbines) is proposed in addition to Australia's current 1.5GWe, running at an average annual capacity factor of 30%. The proposed locations for these sites for turbine installation are shown in Figure 5 in blue. *ZCA2020* demonstrates that 40% of Australia's annual electricity demand, 130TWh/year, will be generated by wind turbines.

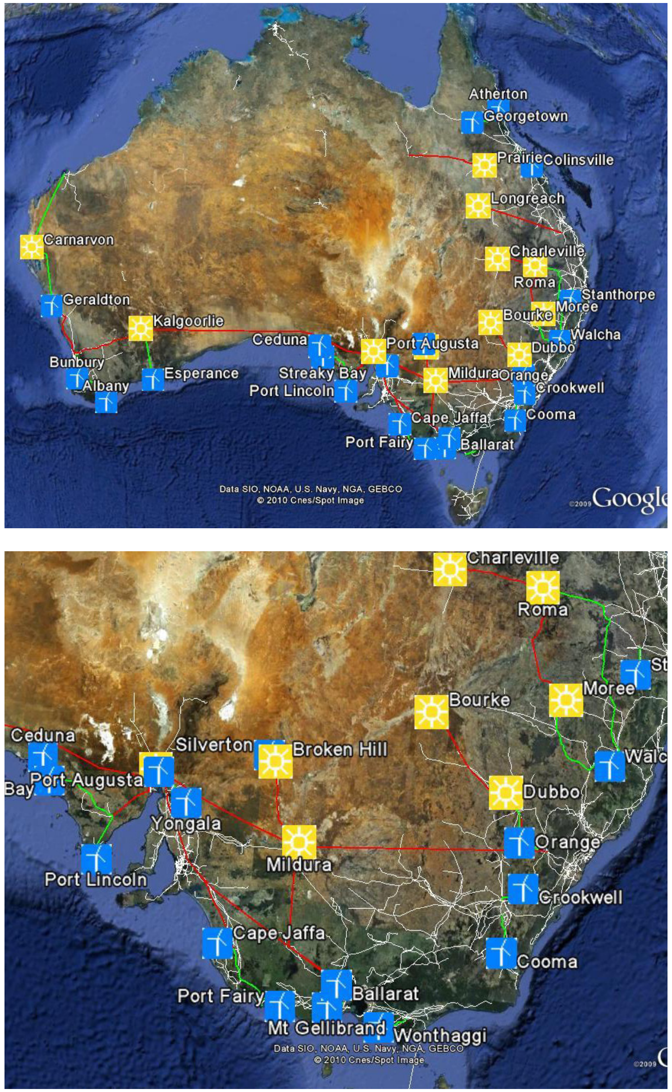

Figure 5 and 6: *ZCA2020* Overview Map. Yellow squares represent solar thermal sites, and blue squares represent wind sites. Red lines represent new HVDC transmission lines and green lines represent new HVAC transmissions lines.

Biomass and Hydro for backup

Biomass combustion and hydroelectricity (using only existing hydro capacity) are used for system backup during extended periods of winter-time cloud cover that coincides at more than one solar plant location. Just 12% of Australia's annual crop residual wheat straw resource would provide 10 full days back-up, equivalent to running 50% of the CST plants at 100% capacity for the period. Combustion in simple burners annexed to the molten salt storage at CST plants allows the use of existing electricity generation and transmission infrastructure, minimising the additional cost. Pelletisation increases the energy density of wheat straw biomass and reduces the cost of transporting it to CST power stations. Thereby the ZCA2020 system is able to ensure reliable supply of electricity year-round.

Biogas, produced by fermentation of organic waste streams, can provide a renewable form of combustible gas to supply current demand for natural gas that cannot be electrified. Methane produced in bioreactors is a viable feedstock for industrial processes currently reliant on natural gas for carbon-based chemical reactions. The *ZCA2020 Sector Report: Land Use and Agriculture* will also detail how biomass energy generation is coupled with bio-char carbon draw-down and sequestration to remove carbon from the atmosphere.

Electricity Transmission Upgrades

Transmission upgrades are necessary to deliver the CST and wind power to demand centres (such as cities and industrial sites), and achieve stability in the electric grid by allowing greater and more flexible transport of electricity around Australia. *ZCA2020* costings include the construction of these electrical transmission lines. A 500 kilovolt (kV) alternating current transmission system will connect new power stations located near populated regions. High-voltage direct current (HVDC) is to be used for low-loss long-distance transmission from remote areas to demand centres increasing supply security and decreasing transmission losses. See Figure 5 for the location of these transmission lines.

Transport Revolution

Australia currently spends approximately AU$30 billion per year on liquid transport fuels, and the cost of these imports increases year on year as domestic oil production sources decline. According to the CSIRO, this annual burden could increase up to 6 times by 2018 [12]. *ZCA2020* identifies avoidance of the high future costs of liquid fuels as a major economic offset to the costs of transforming Australia's energy supply infrastructure. Thus, improving access to public transport and converting the vehicle fleet to electricity (and where necessary range-extending hybrid biofuel-electric vehicles) is needed for climate as well as economic and energy security. Detail on the transition to a zero carbon transport sector will be outlined in the *ZCA2020 sector report on transport* and preliminary results have been used in the final energy supply scenario in the *ZCA2020 stationary energy report*.

Elimination of Natural Gas

In Australia, more end-user energy is supplied by natural gas than by any other commercial energy source. A major use of natural gas in residential, commercial, and industrial situations is space heating, along with industrial furnaces in manufacturing and mining. *ZCA2020* acknowledges that the elimination of natural gas as an energy source is a challenge. Nevertheless, a shift away from fossil gas is achievable and can be done by improving building energy efficiency (by an average of 20%), switching to electrical sources of energy (such as high efficiency heat-pumps and induction cook-tops), while in industrial settings using electrically delivered heat and even direct solar co-generation where appropriate. Further detail on eliminating fossil fuel natural gas from use in the Australian economy will be given in the *Buildings* and *Industrial Processes ZCA2020 sector plans*.

Levelling Demand Peaks

The present Australian electricity supply system experiences very large differences between demand peaks and troughs. For much of the year, energy supply systems operate far below their maximum capacity, while at peak demand times, the system is stressed, sometimes to the point of failure.

Under *ZCA2020*, electricity demand will peak in winter, due to the requirements of electrical heat pumps which will offset existing inefficient gas-fired space heating. For optimal system efficiency, a demand profile much flatter than the present will be achieved via the use of a "smart-grid" to schedule off-peak vehicle battery charging, off-peak heat-pump solar hot water boosting and off-peak heating, cooling and refrigeration. This smart-grid technology will help shift energy use from peak times to off-peak times, thereby stabilising electricity demand.

Investing in the transition

The *ZCA2020 Stationary Energy Sector Report* has found that AU$35-40 billion per year must be invested over a 10 year period in order to transition to a 100% renewable stationary energy sector. Table 1 gives indicative costs over ten years. A full cost breakdown is given in the full report, detailing the investment needed to put in place the energy supply infrastructure – wind, solar, biomass installations and associated electrical transmission upgrades. Later reports will look at the costs of demand-side investment – i.e. the *Industrial Processes Sector Report* will detail the costs associated with large-scale conversion of industrial gas to electrical heating and the Transport Sector Report will look at electric vehicle and public transport investments required.

Component	AUD$,Bn
CST	$175
Biomass	$8
Biogas	$6
Wind	$72
Transmission	$92
TOTAL	**$353**
Offgrid CST	$17
TOTAL + Offgrid	**$370**

Table 1: Indicative investment required for ZCA2020 Stationary Energy plan.

Offsetting the Costs of Transformation

In addition to the savings generated by ending oil imports, the costs outlined in table 1, are offset by all of the following costs that would be incurred under a business as usual (BAU) scenario:

- annual coal costs
- annual natural gas costs
- annual fossil-fuel plant water costs
- fossil-fuel plant replacement and upgrade costs
- other fossil-fuel plant operating and maintenance costs

The *ZCA2020 stationary energy transition* involves a net additional investment of AU$200 billion (in net present value terms) from now until 2050 compared with BAU. 2050 is when the renewable energy infrastructure is expected to need replacing or upgrading. However, this is without including any future carbon price or escalating oil prices, which if included, show that *ZCA2020* is in fact economically favourable. These cost scenarios are explored further in the full report.

Australia's annual Gross Domestic Product (GDP) is approximately AU$1.2 Trillion [13]. The investment required for *ZCA2020* implementation over the ten years would therefore be 3-3.5% of GDP. Given the urgent necessity of transitioning to a 100% renewable economy within the given timeframe, this is a sensible expenditure.

Resources Required

The *Stationary Energy Sector Report* also examines the resources required – labour and materials – to achieve the transformation, as well as the scale-up of manufacturing capacity required. No major resource constraints were identified although priority will need to be placed on climate risk mitigation activities versus other business as usual economic endeavours. The two graphs in Figure 7 show the amount of concrete and steel required for the wind and CST components of the *ZCA2020 plan*, compared beyond ZERO emissions

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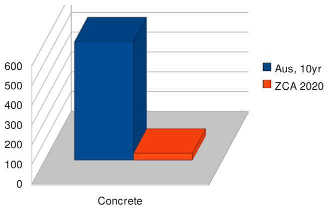
to the total Australian production over the next ten years. The steel figure is inclusive of the steel that is eventually smelted from Australia's vast iron ore exports. Given the amount of economic activity that is already deployed towards using these resources elsewhere, it will be well within our capability to direct a suitable proportion of effort towards construction of the *ZCA2020 plan*. This will create over 75,000 construction jobs at the peak of installation, less than 8% of Australia's existing construction workforce. 80,000 ongoing jobs in operations, maintenance and manufacturing will be created, much more than the existing fossil energy supply workforce.

CST + Wind Concrete requirements
Million tonnes



CST + Wind Steel requirements
Million tonnes, including ore exports

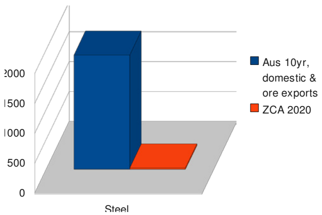


Figure 7: Concrete and steel requirements for *ZCA2020* CST and wind plants.

Conclusion

The *Stationary Energy Sector Report* concludes that there are no technological impediments to transforming Australia's stationary energy sector to zero emissions over the next ten years. The costs of transformation are adequately offset by savings made from shifting away from the business as usual scenario. No resource constraints were identified. With adequate societal and political commitment and regulatory support, the goal of an efficient and competitive zero-emissions stationary energy sector is well within Australia's reach.

THE TRANSITION DECADE

What next?

The full *Zero Carbon Australia 2020 Stationary Energy Plan* will be released in the first half of 2010. The *ZCA2020* team will then focus its efforts on the buildings, transport, industrial processes, replacing coal export revenue and land use sectors. We will then update the stationary energy plan with a version 2.0 release.

For more information on the *ZCA2020 project*, download this executive summary and join our mailing list to be informed when the full *ZCA2020 Stationary Energy Report* is released: **www.beyondzeroemissions.org**

Your support

We need your help to finish this visionary project. Beyond Zero Emissions relies on independent donations to produce our work and on volunteers to help research and write our plans.

We are non-profit, mostly staffed by volunteers and operate with very low overheads, so your donation goes further!

Why Beyond Zero Emissions?

- Solutions focused organisation
- No compromise on the climate science – we look into solutions to the climate crisis at a scale that will actually solve the problem
- Cutting-edge, visionary research
- Collaborative approach

To donate to the *ZCA2020 project* visit:
www.beyondzeroemissions.org/donate

To volunteer on the *ZCA2020 project* please visit:
www.beyondzeroemissions.org/volunteer

The *ZCA2020 project* is supported by the Climate Emergency Network and Climate Positive.

This report has been designed to read on screen.

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