CLEAN ENERGY SOLUTIONS TO CLIMATE CHANGE

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1. INTRODUCTION

Australia has one of the world's highest per capita levels of greenhouse gas emissions, in part because of our heavy reliance on fossil fuels for electricity generation. Fossil fuels provide 93% of our electricity (83% coal, 10% gas) and renewables just 7% (mostly hydroelectricity).

A transition to low-carbon electricity sources is imperative in order for Australia to play its part in global efforts to minimise the adverse impacts of climate change.

The low-carbon options are clean energy (energy efficiency and renewables) or nuclear power. A strong body of evidence demonstrates that clean energy solutions will enable Australia to sharply reduce greenhouse emissions in the electricty sector without the need for nuclear power.

Energy efficiency measures are capable of generating large reductions in greenhouse emissions and can do so more cheaply and quickly than nuclear power. Therefore, investing in nuclear power instead of energy efficiency measures could exacerbate and accelerate climate change.

Renewable energy sources can also be deployed more rapidly than nuclear power, and credible scenarios have been developed which map out plans for the progressive replacement of fossil fuels with renewable energy. The main qualification is that it may be necessary to rely on gas for some fraction of Australia's electricity generation while some renewable energy sources are deployed on a commercial scale.

2. ENERGY EFFICIENCY – DOING MORE WITH LESS

Energy efficiency means using less energy to provide the same energy services. Energy conservation means using less energy by reducing energy services. In the power sector, efficiencies can be made at every point along the production chain from improvements in power plant technology, to reductions in the power lost through transmission, to changes in the end use of energy. The greatest potential for energy efficiency is in the residential and commercial sectors with many of the potential reductions coming from the design of appliances and buildings.

Both energy efficiency and conservation offer many low and negative net cost options. For consumers the large economic savings from energy efficiency can pay for a major part of the additional costs of renewable energy.

Numerous studies envisage energy efficiency and conservation doing much of the 'heavy lifting' to reduce greenhouse emissions.

A 2007 Australian Bureau of Agricultural and Resource Economics study estimated energy efficiency would directly account for 55% of Australia's carbon abatement by 2050 and 58% of global abatement (Gurney et al., 2007). The report notes: "The majority of abatement in the short term is achieved through the uptake of currently available energy efficient technologies in production and end use sectors such as households, transport, services and industry. These short term improvements play a critical role in reducing requirements for new energy infrastructure. The decreased requirement for new emissions intensive energy infrastructure in the short term potentially plays an important role in achieving large emission reductions in the long term."

The International Energy Agency (2008) estimates that energy efficiency will account for around 43% of global emission abatement to 2030 in a scenario where global carbon dioxide levels stabilise at 450 ppm. Renewable energy sources are expected to generate 21% of the emissions reductions and nuclear power just 6%.

McKinsey & Co (2008) ranked carbon abatement strategies from cheapest to most expensive, and showed many energy efficiency strategies have a negative 'cost'. The McKinsey report maps out greenhouse emissions reductions opportunities leading to a 30% reduction in overall emissions by 2020 and 60% by 2030. The report assumes uptake of carbon capture and storage but not nuclear power. Energy efficiency does much of the 'heavy lifting':

"Significant quantities of 'negative-cost' opportunities are available. These opportunities would allow Australia to reduce emissions in 2020 by 20 percent below 1990 levels at no net cost to the economy. This is because the contribution to the economy of the negative cost opportunities is enough to pay for other abatement measures up to a marginal cost of A$62 per tonne CO2e ... For 2030, an equivalent analysis suggests reductions of 35 percent are achievable at no net cost. ...

"We estimate that by 2020, almost 80 Mt, or 25 percent of the total reductions potential, can be realised with positive returns. Most of these positive return (or 'negative-cost') opportunities are energy-efficiency measures related to improvements in buildings and appliances. Many can be categorised as market failures arising from misaligned incentives, for example, those between builders and tenants, where it benefits the tenant but not the builder to install insulation or energy efficient lighting. ... For 2030, almost 20 percent of the measures examined present net economic benefits ..."

3. ENERGY EFFICIENCY VERSUS NUCLEAR POWER

A comparison of the McKinsey (2008) and Switkowski (2006) reports shows that energy efficiency can deliver reductions in greenhouse emissions much more quickly than nuclear power, much more cheaply, and without unwanted by-products. These two scenarios are comparable in that they reduce annual CO2-e emissions by 66-70 million tonnes (Mt):

McKinsey report:
* Energy efficiency largely responsible for an annual 12% (66Mt) reduction in emissions by 2030 compared to 1990 emissions.
* Cost savings from energy efficiency are such that overall emissions can be reduced by 35% (191 Mt) below 1990 levels by 2030 at no net cost.

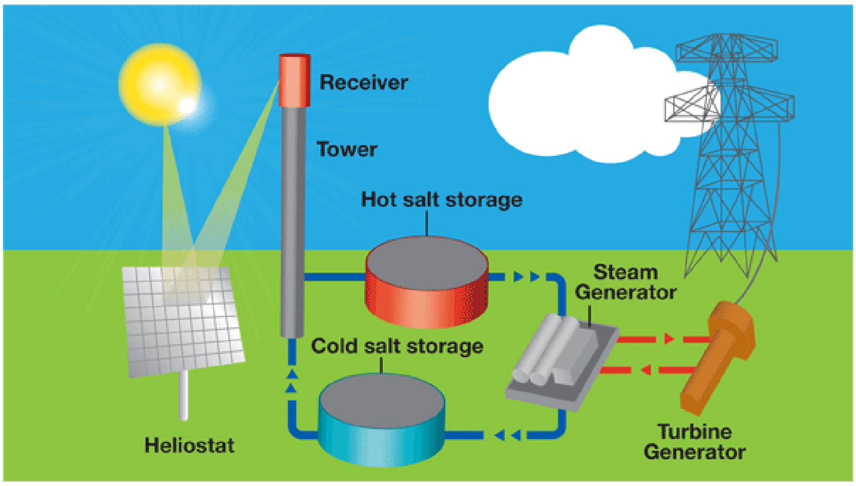
Switkowski report:
* Nuclear power has no capacity to contribute to emissions reductions in Australia by 2020 and limited capacity to reduce emissions by 2030 (except in the unlikely event of a near-term decision to build reactors).
* Building 12 power reactors by the year 2050 reduces annual emissions by 8% (70 Mt) compared to business-as-usual if all the reactors displace black coal. (In a 'fast build' scenario 12 reactors could come on-line sooner.)
* Capital cost: A$48-72 billion (Switkowski, 2009)

Over a 50 year lifespan, the 12 reactors in the nuclear scenario would:
* Produce 18,000 tonnes of high-level nuclear waste (spent nuclear fuel).
* Be responsible for 430 million tonnes of low-level radioactive tailings waste at uranium mines (assuming that it is sourced from Olympic Dam).
* Produce 180 tonnes of weapons-useable plutonium (sufficient for 18,000 nuclear weapons).

4. RENEWABLE ENERGY TECHNOLOGIES

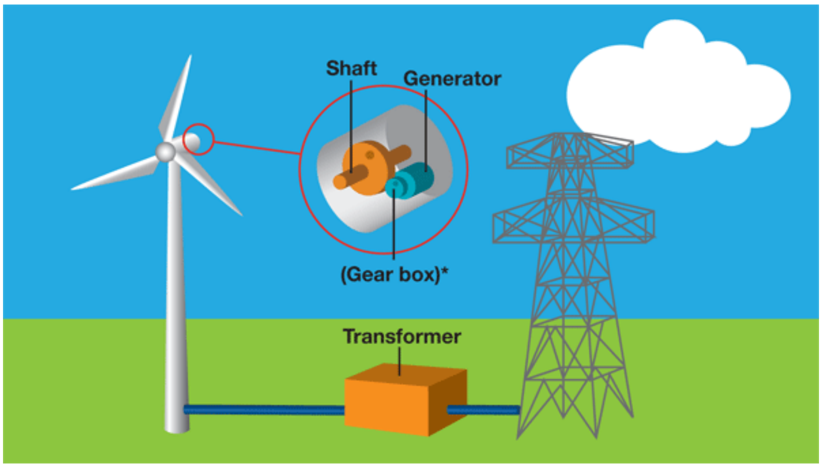
Solar photovoltaics (PV) is a method of generating electrical power by converting solar radiation directly into electricity using semiconductors.

Solar thermal with storage or concentrating solar power uses mirrors to focus the sun's rays onto a focal point. Heat is used to produce steam which powers a turbine to generate electricity. At night, or if the sun is blocked by clouds, the prior storage of heat (e.g. in molten salts) allows the power plant to keep operating.

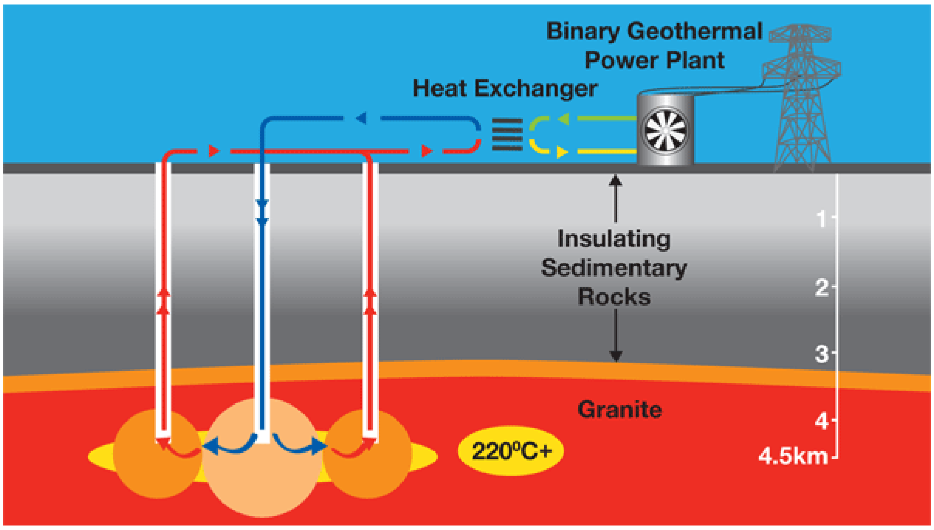


Solar electricity with storage.

Wind power uses the prevailing wind resource and turns that kinetic energy into electrical power. Instead of driving a turbine using steam from burning fossil fuels, the turbine is spun from the rotation of the blades.



Geothermal energy uses underground heat to make high-temperature steam which drives a turbine just as in a conventional coal-fired plant. Geothermal resources worldwide are usually associated with volcanis activity but in Australia geothermal resources are associated with heat producing granites several kilmoetres beneath the earth's surface. A geothermal energy rig consists of two to three wells that drill down to the hot rocks, and a turbine on the surface. Water is pumped down one well and once it reaches the hot rocks, the water heats up to create pressurised steam. The steam reaches the surface, spins the turbines to generate electricity, before being cooled back to water and recirculating down the well.



Bioenergy is energy that comes from organic matter (material derived from plants and animals). Bioenergy fuels include dedicated energy crops and many different types of waste, for example, sewage, food wastes and crop wastes. These fuels can be stored so bioenergy can directly replace coal- and gas-fired power plants.

Hydroelectricity currently supplies 6% of Australia's electricity. There is limited capacity for growth of hydroelectricity in Australia.

Ocean power uses the oceans' tides, currents or waves to produce electricity. Power comes from the water's movement, i.e. either the changes in height of the tides or the ocean's current. Different technologies adopt different methods for harnessing the ocean's energy.

5. CLEAN ENERGY PLANS FOR AUSTRALIA

Numerous studies have considered the mix of energy sources that could be used to power Australia while sharply reducing our reliance on coal fired power plants. Some of the important criteria are as follows:

* The more practical plans are those that rely heavily on existing technologies already deployed on a large scale.
* The more practical plans avoid heavy reliance on the most expensive electricity-supply technologies.
* The proposed electricity supply scenario must provide reliable electricity, either by avoiding excessive reliance on intermittent sources (e.g. solar PV or wind) or by incorporating energy storage systems.

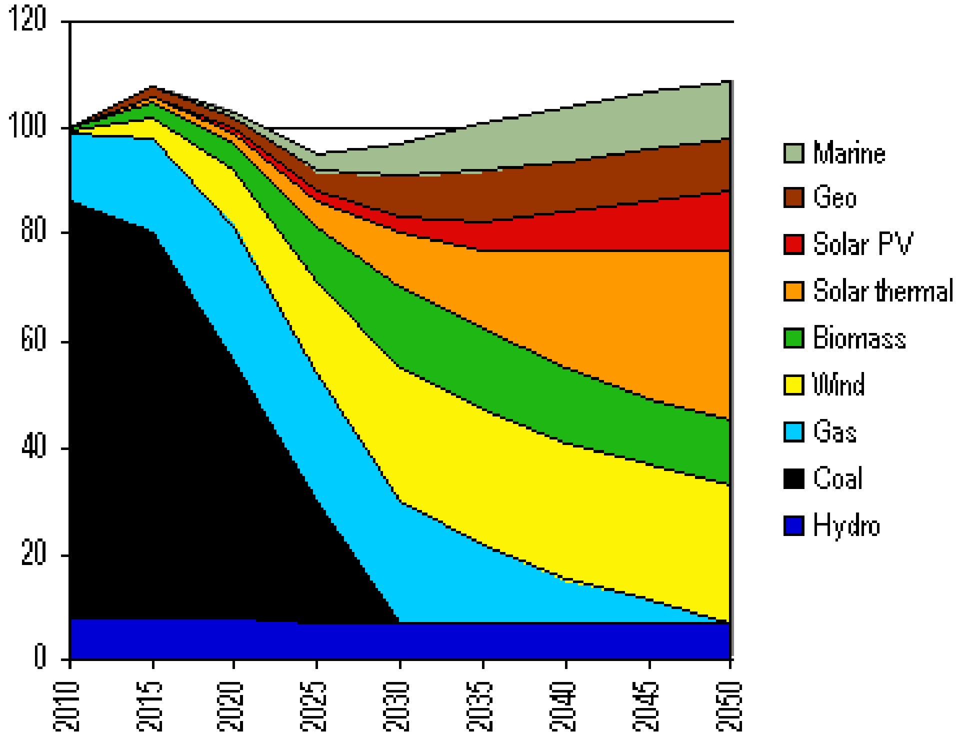
One of the most practical Australian studies was produced by academics for the Clean Energy Future Group (CEFG) (Saddler et al., 2004). It is practical in that it makes virtually no allowance for technical innovation, restricting itself to existing commercial technologies. The study is conservative in that it factors in official projections of economic growth and population growth.

The Clean Energy Future Group proposes an electricity supply scenario which would reduce greenhouse emissions from the electricity sector by 78% by 2040 compared to 2001. The clean energy scenario comprises energy efficiency and conservation measures and electricity supply based on:

* solar 5%
* hydro 7%
* coal (9%) and petroleum (1%) 10%
* wind 20%
* bioenergy 28% − largely from agricultural crop wastes so it is not competing with other land uses
* gas 30%

Cogeneration − the combined production of electricity and useful heat, using turbines and engines on the site where energy is used − plays an important part in the CEFG plan. The plan envisages cogeneration plants providing 15% of total electricity (13% gas, 2% bioenergy).

The CEFG study can be thought of as a baseline study, or a 'worst case' study, because it makes no allowance for developments in important areas like solar-with-storage or geothermal power. University of NSW academic Mark Diesendorf, who contributed to the CEFG study, has proposed a more ambitious scenario which replaces all coal and gas with renewables. Dr Diesendorf states: "By 2030 it will be technically possible to replace all conventional coal power with the following mixes: wind, bioelectricity and solar thermal each 20 to 30%; solar photovoltaic 10-20%; geothermal 10-20%; and marine (wave, ocean current) 10% … There is an embarrassment of riches in the non-nuclear alternatives to coal." (Diesendorf, 2010b.)



This graph illustrates a clean energy plan for Australia in which coal power is phased out by 2030 by means of energy efficiency and conservation, natural gas, and renewable energy. (Source: Diesendorf, pers.comm.)

Dr Diesendorf (2010) writes: "With the temporary assistance of gas, energy efficiency and renewable energy are now sufficiently advanced technologically to substitute for all use of coal in Australia by 2030. Furthermore, the economic savings from demand reduction could pay for the major part of the additional costs of renewable energy. The barriers to this essential transition are vested interests in greenhouse gas emissions: coal, oil, electricity generation, aluminium, steel, cement, forestry based on logging native forests, and some types of agriculture. These vested interests are disseminating fallacies about greenhouse science and greenhouse mitigation. Common fallacies are that making the transition to renewable energy will cost jobs and that renewable electricity is not sufficiently reliable for providing a national electricity supply system."

CSIRO scientist Dr John Wright (2009) has proposed a scenario in which renewables generate over three-quarters of Australia's electricity by 2050:

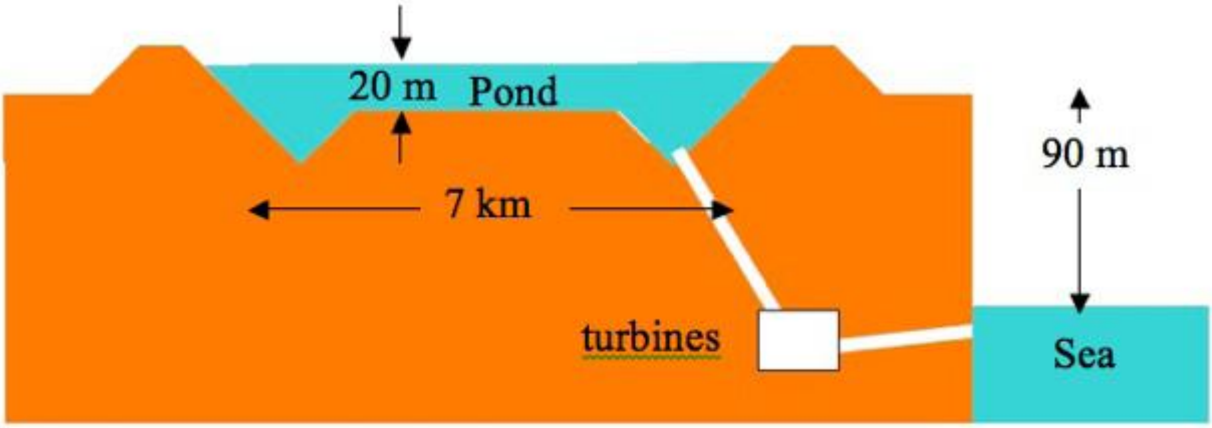
* wind	19.4%
* geothermal	19.0%
* solar thermal	18.3%
* solar PV	12.8%
* bioenergy	5.1%
* ocean energy	0.7%

Dr Wright states: "Overall, increasing renewable energy technology will take out in the order of 200 million tons of CO_2 by 2050 under this scenario. That is equal to about all of our major stationary energy CO_2 emissions now. This is a major, major change."

Australian engineer Peter Seligman (2010) has proposed an energy supply system for Australia based largely on geothermal, wind and solar power. Dr Seligman's conclusions are as follows:
1. In theory, Australia could comfortably supply all of its power requirements renewably.
2. In practice, for some interim period, the use of some non-renewable sources may be necessary but the overall carbon footprint can be reduced to zero in time.

3. The major contributors would be geothermal, wind and solar power.
4. To match the varying load and supply, electricity could be stored using pumped hydro, as it is at present on a much smaller scale. In this case, seawater could be used, in large cliff-top ponds.
5. Energy efficiency would be a key aspect of the solution.
6. A comprehensive modelling approach could be used to minimise the cost rather than the current piecemeal, politically based, ad hoc system.
7. Private transport and other fuel based transport could be largely electrified and batteries could be used to assist with storage.
8. In a transition period, liquid fuel based transport could be accommodated by using biofuels produced using CO2 from any remaining fossil fuelled power sources and CO2 generating industries.

Dr Seligman proposes the construction of a large pumped hydro energy storage system. When electricity is in short supply (e.g. calm, cloudy days), water from a very large pond is run downhill through turbines to generate electricity. At other times, water is pumped up hill to replenish the pond.



Saltwater pond on the Nullarbor to store all Australia's renewable energy. (Seligman, 2010).

Siemens Ltd. (2010), a company with extensive involvement in the energy sector, has mapped out an energy plan for Australia in which the contribution of fossil fuels to electricty generation falls from 93% to around 10% (all of the remaining fossil fuel plants have carbon capture), with the remainder generated by a mix of renewable technologies consisting mainly of wind (18%), solar (35%) and geothermal (17%). Large scale energy storage is provided by a mix of solar thermal and hydrogen.

Siemens chairperson Albert Goller said: "We have many enviable opportunities in Australia such as our abundance of natural resources, and Australia has the potential to be at the forefront of technology. Even the possibility of being a net exporter of clean electricity is realistic for Australia. Implementing technologies will not only help create a sustainable future, but also new skills and job opportunities in remote regions, whilst providing economic growth."

In the Siemens plan, most large-scale transmission interconnectors are High Voltage Direct Current (HVDC), providing significant reduction in losses and thus allowing for efficient, long-distance transmission of renewable energy-generated electricity around the country. Siemens also proposes the development of HVDC links to South East Asia allow export of renewable electricity.

In the Siemens plan, virtually all land transport is electric or hydrogen based. As the majority of power generation is renewable, the road transport fleet becomes virtually greenhouse gas free. A high speed rail network provides efficient transport between major cities. By 2050, 20% of vehicles are hybrids, 55% are electric/hydrogen powered.

Greenpeace (2010) has produced an ambitious 'Energy [R]evolution' blueprint for a renewable energy future in which renewable energy's share of Australia's total generation increases to 75% by 2024 while coal's share reduces to zero by 2020. This scenario would halve annual greenhouse emissions in Australia's energy sector. Employment in the coal industry would drop by 11,000 and renewable energy job numbers increase by 54,000. The electricity supply mix includes contributions from wind (21%), solar thermal (15%), solar PV, geothermal (7%), bioenergy, hydroelectricity and ocean energy.

Another ambitious study is the Beyond Zero Emissions' Stationary Energy Plan (2010). This plan envisages Australia's electricity supply being converted to renewables by 2020. Solar thermal plants with molten salt storage provide 60% of electricity and wind 40%, with back-up from hydroelectricity and bioenergy (crop wastes).

6. PUBLIC OPINION

Australians want to see greater investment in renewable energy, such as wind and solar power, and cuts in the amount of coal used to generate electricity, a 2007 survey of 1200 Australians found. Support for nuclear power came a distant last. The Australian Research Group (2007) poll found 91% support for installing more solar panels, 82% support for more wind farms, 78% support for energy efficiency, and 33% support for nuclear power.

A 2009 poll of 1200 Australians found that 80% of those polled said that the government should give priority to renewables while only 15% favoured priority being given to developing nuclear power. (Clean Energy Council, 2009.)

7. INTERMITTENT RENEWABLES AND ELECTRICITY SUPPLY RELIABILITY

How to deal with the intermittency of some renewable energy sources (wind, solar)? How to reconcile that intermittency with the need for reliable electricity supply? Options include limiting the contribution of intermittent energy sources such that overall electricity supply reliability can be ensured, and/or the use of energy storage systems.

Dr Mark Diesendorf (2010) writes:

"Some sustainable energy sources and measures are at least as reliable as coal power. These include demand reduction by means of energy efficiency, energy conservation and solar hot water, and renewable electricity supply by hydro with large dams, bioenergy, solar thermal power with thermal storage and geothermal power. They can all be used to reduce the demand for base-load coal without reducing the reliability of the generating system.

"What about fluctuating renewable electricity sources, such as wind, run-of-river hydro, solar without storage, and wave power? They simple add fluctuating sources to an electricity supply system that is already designed to handle fluctuations in demand and conventional supply. All base-load power stations, including coal and nuclear, are partially reliable and therefore require some back-up. Breakdowns of coal and nuclear power stations occur less frequently than fluctuations in the wind and sunshine, but when coal and nuclear do break down, they are off-line for longer periods than lulls in the wind or periods of overcast and darkness. To compare the reliability of coal and nuclear with that of wind and sun in an electricity grid, we have to compare the reliability of the whole generating system with and without the renewable electricity sources.

"Both computer modelling and practical experience show that the existing system can handle small penetrations of fluctuating renewable electricity sources into the grid. For large penetrations, wind in particular can substitute for base-load coal-fired power stations, provided either some additional peak-load plant is installed or the grid is interconnected into a larger neighbouring grid, in order to

return the generation reliability to the original level. For instance, Denmark is planning to increase its wind energy contribution to 50% of total annual electricity generation by increasing the capacity of its transmission link to Norwegian hydro. Since Australia cannot do this, it will need some additional peak-load capacity, in the form of gas turbines or hydro. The amount of additional back-up increases with increasing wind penetration, but decreases as the geographic dispersion of the wind farms increases. For a geographically-dispersed wind energy penetration of 25% of total generation, the additional peak-load capacity required to maintain reliability would be a small fraction of the wind capacity. Since the back-up only has to be operated infrequently, it can be considered to be reliability insurance with a low premium. By the way, the gas turbine could be fuelled with biofuels produced sustainably."

Click here to download
Mark Diesendorf, 2010, The Base Load Fallacy and other Fallacies disseminated by Renewable Energy Deniers
http://www.choosenuclearfree.net/wp-content/uploads/2010/11/BP16-BaseLoad-rev2010.pdf

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Wright, John, 4 August 2009, 'Australia's renewable energy future: The contribution of renewables in Australia's future energy mix, AAS Public Lecture Series', <www.science.org.au/events/publiclectures/re/wright.html>.

9. MAPS OF AUSTRALIAN RENEWABLE ENERGY PLANTS

Clean Energy Council, interactive map of all renewable energy power plants over 100kW in Australia. <www.cleanenergycouncil.org.au/cec/resourcecentre/plantregistermap>

Renewable Energy Atlas of Australia
<www.environment.gov.au/settlements/renewable/atlas>
The interactive Renewable Energy Atlas provides information on Australia's renewable energy resources. The atlas profiles wind, solar, geothermal, ocean energy and bioenergy resources. There is also contextual data such as power plants, transmission lines, roads, land tenure and climate information.

10. FURTHER READING

Australia

- Australian Academy of Science - 2009 renewable energy lecture series:<www.science.org.au/events/publiclectures/re/index.htm>
- Clean Energy Council (Australia) <www.cleanenergycouncil.org.au>
- Clean Energy Council renewable energy fact sheets:<www.cleanenergycouncil.org.au/cec/resourcecentre/factsheets.html>
- ACF renewable energy factsheets <www.acfonline.org.au/default.asp?section_id=36>
- Greenpeace fact sheets (wind, solar, geothermal, cogeneration)<www.greenpeace.org.au/climate/GI-ER-Report2010.php>
- Clean Energy Future for Australia (national and state reports)<http://wwf.org.au/ourwork/climatechange/cleanenergyfuture>
- Mark Diesendorf, 2010, The Base Load Fallacy and other Fallacies disseminated by Renewable Energy Deniers,<www.energyscience.org.au/factsheets.html> or direct download <http://www.energyscience.org.au/BP16/BaseLoad.pdf>
- References to literature on clean energy options, with an emphasis on 'deep cuts' studies which detail the methods by which large reductions in greenhouse emissions can be achieved (without nuclear power). <www.foe.org.au/anti-nuclear/issues/clean-energy/research>
- Economics Report: Climate Leadership an Affordable Investment, CSIRO et al., <www.climateinstitute.org.au//index.php?option=com_content&task=view&id=130&Itemid=1>
- The Australian Business Roundtable on Climate Change <www.acfonline.org.au/articles/news.asp?news_id=755>
- Options for Moving to a Lower Emission Future, WWF-Australia, AGL and Frontier Economics, 2006, <www.wwf.org.au/publications/lower-emission-future> or<www.wwf.org.au/news/reducing-greenhouse-gas-emissions-is-affordable-and-achievable>

- Fast-tracking Victoria's clean energy future to replace the Hazelwood Power Station,<www.environmentvictoria.org.au/replacehazelwood>
- Solar thermal electricity as the primary replacement for coal and oil in U.S. generation and transportation, David R. Mills and Robert G. Morgan,<www.ausra.com/pdfs/ausra_usgridsupply.pdf>
- Energy Today - references to significant energy reports (Australian and international). <www.energytoday.com.au>. See esp. energy reports<www.energytoday.com.au/publications/recent-energy-publications.php> and and renewable enegry reports<www.energytoday.com.au/publications/renewable-energy-publications.php>
- Mark Diesendorf, 2009, UNSW Press, Climate Action: A campaign manual for greenhouse solutions
- Wind Farms: The facts and the fallacies, Andrew Macintosh and Christian Downie, Australia Institute, Discussion Paper Number 91, October 2006, <www.tai.org.au/documents/downloads/DP91.pdf>
- Hung out to dry: Federal neglect of renewable energy research and development in Australia, report by Greenpeace Australia Pacific, September 2007, <www.greenpeace.org/australia/resources/reports/climate-change/hung-out-to-dry-federal-negle> or direct download: <www.greenpeace.org/raw/content/australia/resources/reports/climate-change/hung-out-to-dry-federal-negle.pdf>
- ABARE, April 2009, Energy in Australia 2009, <www.abare.gov.au/publications_html/energy/energy_09/auEnergy09.pdf>.This ABARE report covers all aspects of energy production and use, from natural resources through to final consumption, including energy research, energy efficiency, the development of renewable energy, low emission technologies, and alternative fuels.

Information portals / collections of links to sustainable energy literature:

- Clean Energy Council links <www.cleanenergycouncil.org.au/cec/policyadvocacy/usefullinks.html>
- Environment Sustainability links <www.ecosustainable.com.au/links.htm>
- Alternative Energy www.alternative-energy-news.info
- Energy Planet - Renewable Energy Directory <www.energyplanet.info>
- Energy Bulletin - sustainable energy section <www.energybulletin.net/taxonomy/term/9?page=1>
- International Energy Agency - energy issues by topic <www.iea.org/subjectqueries/index.asp>
- Research Institute for Sustainable Energy (Murdoch Uni) information portal. <www.rise.org.au/info>
- CSIRO - Renewable Energy <www.csiro.au/csiro/channel/ich2j,,.html>

International reports

- A global renewable energy scenario, Sørensen B and Meibom P, 2000, International Journal of Global Energy Issues 13 (1/2/3), DOI: 10.1504/IJGEI.2000.000869.
- Green Energies 100% Renewables by 2050, <www.i-sis.org.uk/GreenEnergies.php>, ISIS Report 30/09/09.
- WWF, 2007, "Climate Solutions: WWF's vision for 2050", <http://assets.panda.org/downloads/climatesolutionweb.pdf>, The findings show that known energy sources and proven technologies could be harnessed between now and 2050 to meet a projected doubling in global demand for energy while at the same time achieving the necessary significant drop (about 60-80 per cent) in carbon dioxide emissions to prevent dangerous climate change.
- European Renewable Energy Council (EREC) and Greenpeace International, January 2007, "Energy [R]evolution: A sustainable World Energy Outlook" , <www.energyblueprint.info> This

blueprint for halving global greenhouse emissions by 2050 includes 10 regional studies and a series of national studies inc. Australia, China, India, Japan, USA, etc.

- International Renewable Energy Agency (IRENA) <www.irena.org>
- Renewable Energy World <www.renewableenergyworld.com>
- New Scientist - articles on many energy / clean energy issues: <www.newscientist.com/topic/energy-fuels>
- REN21 - Renewable Energy Policy Network for the 21st Century, Summary of global renewable energy developments: <www.worldwatch.org/taxonomy/term/444> and <www.ren21.net>
- The Technical and Economic Feasibility of a Carbon-Free and Nuclear-Free Energy System in the United States, Arjun Makhijani, March 2009, <www.downtheyellowcakeroad.org/icws309w2/index.cfm?ID=96C8E1AE-AB14-404C-ABB018DB487A1150> or direct downoad <www.downtheyellowcakeroad.org/userfiles/file//Renewable_electric_system-Makhijani2009.pdf>