Greenhouse Solutions with Sustainable Energy

A Submission to Garnaut Climate Change Review

Dr Mark Diesendorf

Institute of Environmental Studies
University of New South Wales
UNSW Sydney NSW 2052
Email: <m.diesendorf@unsw.edu.au>
phone: (02) 9385 5707

The author

At various times Dr Diesendorf was a Principal Research Scientist in the CSIRO Division of Mathematics and Statistics, Professor of Environmental Science at UTS, vice-president of the Australia New Zealand Society for Ecological Economics, and a committee-member of the Australia and New Zealand Solar Energy Society. He is the author of *Greenhouse Solutions with Sustainable Energy*, UNSW Press, 2007, and many scholarly papers and reports on renewable energy and energy policy.

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Executive Summary

This submission addresses the potential role of ecologically sustainable energy (shortened to 'sustainable energy') in reducing Australia's greenhouse gas (GHG) emissions and the government policies needed to implement it. 'Sustainable energy' is defined here to be the efficient use of renewable energy. In addition, natural gas, the least polluting of the fossil fuels, is considered here to be a valuable but short-lived adjunct energy source during the transition to a sustainable energy future. Within the context of sustainable energy technologies and measures, this submission focuses on the second and fourth Terms of Reference. Before doing so, it points out the international significance of Australia's actions.

International impacts of Australia's mitigation actions

Contrary to the 'spin' disseminated by some vested interests and some politicians, actions by Australia to reduce substantially its greenhouse gas (GHG) emissions would have a big positive international impact. This is because Australia is the world's biggest per capita greenhouse gas emitter and, until the new Labor government changes Australia's stance, one of only two industrialised countries refusing to ratify the Kyoto Protocol. Actions by Australia to ratify Kyoto, to support a post-2012 greenhouse reduction agreement with strong targets and timetables and to mitigate its own emissions would add to the internal and external pressures on the Bush administration to change its position and would enhance Australia's role in international climate change forums.

Once the USA and Australia have ratified Kyoto and committed to a post-2012 international agreement with strong targets and timetables, the sustainable development forces within China would be strengthened and it would become much more likely that China would join a post-2012 agreement, possibly based on the principle of 'contraction and convergence'.

Role of a short-term target

The growing body of scientific evidence, that there are several positive feedback (amplification) processes pushing planet Earth towards runaway climate change, implies that the developed countries must urgently stop their growth in emissions and achieve substantial reductions in emissions before 2020.

According to business-as-usual projections published by the Australian Greenhouse Office, by far the biggest component of growth in Australia's GHG emissions from 2004 to 2020 will come from energy use, including transport. Accordingly, this submission focuses on energy, while recognising that emissions will also have to be reduced in other sectors, notably agriculture and forestry. Ecologically sustainable energy, comprising efficient energy use and renewable energy, together with natural gas are the *only* technologies and measures capable of achieving large reductions in Australia's energy-related GHG emissions before 2020. Neither coal with CO_2 capture and sequestration (CCS) nor nuclear power could make a significant contribution before 2020.

A recent scenario study, outlined in this submission, finds that Australia could reduce its annual GHG emissions to at least 30 per cent below the 1990 level by 2020. Sustainable energy plays the major role in this scenario, especially in reducing emissions from electricity and low temperature heat. Sustainable energy can deliver much larger emission reductions beyond 2020.

Policies needed

The principal categories of policies needed to drive the reduction of greenhouse gas emissions by means of sustainable energy are:

- economic instruments (including carbon pricing and other market mechanisms, R&D funding and the removal of some existing subsidies);
- regulations and standards (especially when markets fail, as they generally do with energy efficiency);
- education, training and information; and
- institutional change (e.g. fostering energy service companies; creating federal and state government agencies to coordinate implementation).

Within these policy categories, the key specific policies required are:

- Mandatory energy rating, labelling and performance standards for all new and existing buildings and all new energy-using appliances and equipment.

- Carbon pricing, either a carbon tax or an emissions trading scheme (ETS) with a tight cap on emissions and auctioned permits.

- Until the carbon price is maintained at a sufficiently high level to enable significant amounts of renewable energy to compete with conventional coal power, the Mandatory Renewable Energy Target (MRET) should be expanded to 25 per cent of electricity by 2020.

- The federal government should immediately use the EPBC Act to place a greenhouse intensity limit of 0.5 tonnes CO_2 per megawatt-hour on all new base-load power stations, in effect banning new conventional coal-fired power stations.

- Funding for research and development of sustainable energy technologies should be greatly increased, with particular attention being given to energy efficiency, solar electricity, bioelectricity and second-generation biofuels.

- Part of the revenue raised by a carbon tax or auctioned emissions permits should be dedicated to assisting low-income earners to improve their efficiency of energy use and to shift from electric hot water to solar and other low-emission hot water systems.

These policies must be implemented by federal and state governments to set the framework for action by business and the community at large.

This submission rejects the notion that a carbon price alone is sufficient to achieve the environmental goal, for the following reasons:

- As a result of political pressures by vested interests, an ETS could be set up in a manner that transfers windfall profits to big greenhouse gas emitters, without reducing emissions.

- Even if a potentially effective ETS is set up, political pressures could lead to such a low initial cap on emissions that the carbon price may take a decade or more to reach a sufficiently high level to produce a change in the economic structure (including the energy supply system) that is sufficient to reduce Australia's greenhouse gas emissions substantially. However, government measures – such as an expanded MRET, a ban on conventional coal-fired power stations, R&D grants, rebates on the capital cost of residential and commercial PV systems, and funding for improvements in urban and intercity rail – could be implemented almost immediately.

- Even a working, comprehensive ETS or other form of carbon pricing will have little impact on efficient energy use and other technologies or measures that are subject to market failure. Furthermore, carbon pricing is likely to be too low for the foreseeable future to assist technologies that are currently very expensive while having huge potential: e.g. solar electricity.

The whole purpose of carbon pricing must be to reduce greenhouse gas emissions by changing the economic structure to one that is much less greenhouse-intensive. It would be a waste of time and money to set up a carbon pricing system that is either ineffective or too slow. The only effective options are either a carbon tax or an ETS with the following properties:

- a tight initial cap on emissions, with the cap being progressively tightened every three years or less;
- allocation of all emission permits by auction at the outset;
- emission permits *not* to be permanent property rights;
- no exemptions for greenhouse-intensive industries, apart from border adjustments, as discussed in Subsection 4.2.4;
- no 'safety valve' to limit the carbon price.

Because there are so many ways to subvert the effectiveness of an ETS, this submission favours a carbon tax, with appropriate measures to assist low-income earners to save energy and reduce their energy bills.

Economic aspects and targets

Cost-Benefit Analysis suffers from the limitation of being unable to handle quantitatively the different types and magnitudes (some unknown) of risk associated with different costs and benefits. This means that it is impossible to determine the optimal rate of emission reduction by an objective analysis. If reduction is too slow, the risk of a rapid amplification of global warming becomes high, while if the reduction is very fast, governments may experience political risks and the cost of stranded assets will become high. Ultimately, commonsense is needed to set short-term targets that will be sufficiently high to begin the process of radically changing the energy system. To do this will require an initial carbon price of at least $40 per tonne of CO_2. This would allow wind power and a few limited forms of bioelectricity to compete with conventional coal power.

Because of their smaller technological scales compared with coal power and nuclear power, energy efficiency and renewable energy technologies are highly suitable for local manufacture and so can create far more jobs in Australia, per unit of energy supplied or saved, than fossil or nuclear fuels.

If we take a narrow economic view that ignores external costs, then all supply-side alternatives to fossil fuels in the absence of CCS will be much more expensive for the foreseeable future. However, even in this case it can be argued that the sustainable energy solution is likely to be less expensive than coal with CCS. This is because the latter approach is usually presented as a means of supplying endless growth in energy demand. In such scenarios, efficient energy use plays a very minor role and the concept of stabilising demand is non-existent. In contrast, within sustainable energy scenarios, efficient energy use plays a major role and the stabilisation of energy demand is often regarded as essential in the long term. The economic benefits of efficient energy use are particularly large when efficient energy use competes with the *retail* prices of energy at points of use. Thus, in sustainable energy scenarios for the residential, commercial and light industrial sectors, the economic benefits of efficient energy use can pay for a large fraction of the additional costs of renewable energy.

The bogey of the 'rebound effect'[1] can be readily eliminated by providing users of energy services with 'packages' of energy efficiency and renewable energy with zero or small positive costs. For example, the installation of solar electricity on a home would be mostly funded from the economic savings derived from making the home much more energy and greenhouse efficient.

Another fallacious objection to assigning a major role to energy efficiency is based on the 'general equilibrium' assumption of most macroeconomic models. This is equivalent to assuming a competitive market for energy efficiency, an assumption that is contracted by the observation of several different types of market failure.

If we take a broader economic view, that recognises the external costs of fossil fuels, especially the costs of global warming, then sustainable energy becomes even more economically desirable. Reducing greenhouse gas emissions need not be highly expensive from a societal viewpoint, particularly if action is commenced immediately, following a coherent, measured strategy. However, if further delays are made, then an acceleration of global climate change could drive a sudden retirement of much existing infrastructure, imposing considerable economic losses on the big greenhouse gas emitters. These losses would be transferred to consumers.

Conclusion

Sustainable energy, based on existing technologies with small improvements, and natural gas are together capable of reducing Australia's greenhouse gas emissions from the AGO's business-as-usual 'with measures' projection of 27 per cent above the 1990 level by 2020 to about 13 per cent below the 1990 level by 2020. The fallacies, myths and 'spin' that have been used by vested interests to denigrate sustainable energy have no substance. No other energy technologies are capable of achieving such large reductions before 2020. Incorporation of measures and technologies in the non-energy areas (e.g. agriculture and forestry) can further reduce emissions to at least 30 per cent below the 1990 level by 2020.

[1] Saving energy saves money which is then invested in more energy use.

Beyond 2020, sustainable energy could achieve much greater reductions. A general case can be made that sustainable energy is the least-cost set of technologies for reducing greenhouse gas emissions. This is because the economic savings from energy efficiency can pay for a large fraction of the additional costs of renewable energy.

Carbon pricing is a necessary condition for achieving large absolute values of emission reduction, but pricing is not sufficient. It must be supplemented with regulations and standards (especially in cases of market failure), education and information, targeted government funding and institutional change. To commence essential changes to electricity supply, an initial carbon price of $40 per tonne of CO_2 is recommended, rising to $60 per tonne by 2020. A carbon tax is preferable to an ETS, because there are many ways of subverting an ETS to make it ineffective. If an ETS is the government's choice, it must be implemented with the strong conditions listed above.

1. Introduction

This submission addresses the potential role of ecologically sustainable energy (shortened to 'sustainable energy') in reducing Australia's greenhouse gas (GHG) emissions and the government policies needed to implement it. 'Sustainable energy' is defined here to be the efficient use of renewable energy. Natural gas, the least polluting of the fossil fuels, is considered here to be a valuable but short-lived additional energy source during the transition to a sustainable energy future.

Within the context of sustainable energy technologies and measures, this submission focuses on part of the second Term of Reference, namely

> the costs and benefits of various international and Australian policy interventions on Australian economic activity

and the fourth Term of Reference, namely

> recommend medium to long-term policy options for Australia, and the time path for their implementation which, taking the costs and benefits of domestic and international policies on climate change into account, will produce the best possible outcomes for Australia.

In addressing the second and fourth Terms of Reference, the submission emphasizes the need to achieve large reductions in Australia's greenhouse gas emissions before 2020. This urgency is in part the result of new and growing evidence of several positive feedback processes that are amplifying global warming.

- Melting of the Arctic ice cap reduces the reflection of sunlight with the result that the ocean absorbs more solar energy and so global warming is amplified.
- Melting of permafrost releases methane and CO_2 which amplify warming.
- Global warming increases the concentration of water vapour (a greenhouse gas) in atmosphere, which amplifies warming.
- Warming soils release CO_2, which amplifies warming.
- Global warming increases the prevalence and intensity of wild-fires, which release CO_2, which amplifies warming

Much of this evidence has been published very recently, that is, after the Intergovernmental Panel on Climate Change closed data inputs to its 2007 report. Since this evidence will no doubt be reviewed in detail in submissions by climatologists, it is simply listed here without referencing. There are few negative feedbacks to counter these and other positive feedbacks. If these amplification processes are allowed to continue, they will inevitably produce runaway global warming, accelerated sea-level rise (one or more metres by 2100), and a vastly different climate on planet Earth.

The present report also comments briefly on the third Term of Reference,

> The role that Australia can play in the development and implementation of effective international policies on climate change

in order to refute the fallacy that Australia's actions to reduce global warming are unimportant on the world stage.

In preparing the ground for a discussion of policies need to reduce Australia’s greenhouse gas emissions by implementing sustainable energy, this submission also refutes a number of fallacies that have been disseminated by vested interests and other opponents of sustainable energy.

2. Fallacies about greenhouse solutions

Fallacy 1: Since Australia has only 1.4 per cent of global GHG emissions, ratifying Kyoto and reducing Australia's emissions would have negligible international impact

It is ironic that this statement is often made by politicians, who must be aware that the international *political* impact of Australia changing its stance would be huge. As of 2007, the USA is the world's biggest GHG emitter and Australia the world's biggest per capita emitter. Australia is one of only two industrialised countries that (as of November 2007) has not to ratified Kyoto. If Australia ratified Kyoto, supported strong targets for the next international agreement post-2012 and took substantial action to reduce its own emissions, it would add to the existing international and internal pressures on the USA to ratify. It would also send a strong signal to the whole world. Ratification by the USA and Australia is a necessary pre-condition for bringing developing countries such as China and India into an international agreement with targets.

Fallacy 2: Coal power with CO_2 capture and sequestration (CCS) is the principal greenhouse solution.

Coal power with CCS is an unproven technological system. Although pilot plants could be built in Australia before 2020 if the government pours in enough money, this would still be a long way from full-scale commercial production with a high confidence in safety. The risks of CO_2 escapes are substantial.

The interdisciplinary expert study on *The Future of Coal* from the Massachusetts Institute of Technology (Ansolabehere, 2007) envisages that coal with CCS may begin to make a noticeable contribution on a global scale around 2025 and may overtake renewable energy on a global scale around 2045. A similar result regarding CCS noticeable contribution was obtained in an earlier assessment by the Australia Institute (Saddler, Riedy & Passey, 2004). We cannot afford to delay substantial greenhouse mitigation until such time as coal power with CCS *may* become commercially available.

Fallacy 3: Australia could develop the coal with CCS technology and sell it to China.

This is a delusion of grandeur. To develop this technology would require billions of dollars and hence a superpower economy (e.g. USA and EU). Australia should focus on the basic geology, so that, if and when CCS technology is developed overseas, Australia will have identified underground storage sites. In the foreseeable future, the most important role for CCS in Australia will be to separate and bury CO_2 from natural gas at the Gorgon and other gas fields on the North-West Shelf. Fortunately, this is much easier than separating CO_2 from coal.

Fallacy 4: Nuclear power is a suitable alternative or supplementary solution to coal with CCS

Current reserves of high-grade uranium ore will only last several decades at *current* usage rate. Once they are used up, low-grade ore will have to be used. This means that, to produce 1 kg of yellowcake, 10 tonnes or more of rock will have to be mined and milled, using fossil fuels. Under these circumstances, the CO_2 emissions from the nuclear fuel chain will be comparable with those of an equivalent combined-cycle gas-fired power station (Van Leeuwen & Smith, 2007; Diesendorf , 2007a, chapter 12; Diesendorf, 2007d).

Government Ministers and nuclear experts have admitted that Australia's first nuclear power station and associated infrastructure would take 15 years to construct (assuming no public opposition).

Therefore, based on existing technology, nuclear power is neither a short-term nor a long-term solution to global warming.

Fallacy 5: The spent fuel from nuclear power stations cannot be used to make nuclear weapons.

This false claim has been refuted by many experts, including leading US nuclear bomb designer Dr Theodore Taylor, Commissioner of the US Nuclear Regulatory Commission Dr Victor Gilinsky and the US Department of Energy (references in Diesendorf 2007a, chapter 12). A conventional 1000 megawatt nuclear power station produces about 200 kg of reactor-grade plutonium annually, enough for at least 20 nuclear bombs.

There is no good reason to trust future Australian governments not to use spent fuel from nuclear power stations to develop nuclear weapons. Australia's attempts to move in that direction in the 1950s, 60s and 70s have been well documented (Reynolds, 2000; Broinowski, 2003).

It has also been claimed incorrectly that a nuclear power station based on thorium rather than uranium cannot produce a nuclear explosive. In fact, to use thorium as a fuel, it must first be converted to uranium-233, which is fissile and so can be used either to fuel a nuclear reactor or provide the explosive in a nuclear bomb.

Nuclear power and nuclear weapons are intimately linked. In addition to the dual uses of nuclear materials, the training of engineers and technicians for nuclear power provides most of the training required to develop nuclear weapons. The only sure way of avoiding further nuclear weapons proliferation from civil nuclear power is to place the sensitive links in the nuclear fuel chain – uranium enrichment and spent fuel handling – under complete international control.

Fallacy 6: Australia has to choose between coal with CCS and nuclear power.

Neither coal with CCS nor nuclear power could make a significant contribution before the 2020s. Both are dirty and dangerous technologies. Therefore, this is a false choice. However, there is another choice: between unproven, polluting and dangerous coal and nuclear technologies on one hand and safe, proven, sustainable energy technologies on the other hand. Sustainable energy comprises efficient energy use and renewable sources of energy. Natural gas, the cleanest of the fossil fuels, could play a valuable role in the transition to a sustainable energy future.

Fallacy 7: Efficient energy use has little potential.

Detailed engineering studies conducted overseas and within Australia (for example, under the National Framework for Energy Efficiency – see website) show that there is huge potential for *cost-effective* efficient energy use (shortened to 'energy efficiency') which is the cheapest and fastest set of GHG reduction measures. For additional references, see Saddler, Diesendorf & Denniss (2004) and Greene & Pears (2003).

Energy efficiency has been held back by market failure (e.g. split incentives between landlord and tenant; lack of information; lack of appropriate institutional structures such as energy service companies) and other barriers, such as macroeconomic models that assume incorrectly that energy efficiency operates in a competitive market.

Energy efficiency will increase rapidly once governments introduce regulations and standards for energy auditing and labeling and minimum energy performance standards for *all* buildings, appliances and energy-using equipment.

Another barrier to energy efficiency, resulting from a narrow conception of the problem, is the notion of the *rebound effect*, that is widely promulgated by some neoclassical economists. The rebound effect is based on the assumption that the economic savings obtained from energy efficiency will be spent on increased energy use. However, it is shown in Section 5.6 that this effect is exaggerated and furthermore that it is contingent upon the kinds of policies used to reduce emissions. With appropriate policies, the rebound can be eliminated entirely.

Fallacy 8: Renewable energy cannot provide base-load (24-hour per day) power

Bioelectricity, solar thermal electricity with low-cost thermal storage, and hot rock geothermal power (soon to be proven) are all base-load. Energy efficiency and solar hot water can reduce the demand for base-load power. In some circumstances (e.g. in Tasmania), hydro-electricity can provide base-load too. Even large-scale wind power, from geographically dispersed wind farms, can be made as reliable as base-load coal by adding a little peak-load power plant (e.g. hydro or gas turbines), which does not have to be operated frequently (Diesendorf, 2007a & b).

Fallacy 9: Base-load is the only important type of power.

Electricity supply systems cannot be composed of base-load power stations alone. Base-load power stations are operationally inflexible, being unable to follow daily variations in demand. They break down unexpectedly from time to time. They take all day to start up and then have to be operated close to full power day and night.

In Australia a large fraction of base-load coal-fired power is used to provide off-peak electric water heating from midnight to dawn, when electricity demand would otherwise be very low. If off-peak electric hot water were terminated and replaced with solar, gas and electric heat pump hot water, several coal-fired power stations could be retired or not built in Australia and up to 7 million tonnes per year of CO_2 emissions would be saved (see calculation in Appendix A). This calculation takes account of the additional intermediate-load power from combined-cycle gas-fired power stations that would also be required to substitute for the dawn to midnight contribution of those coal-fired power stations.

The water-heating example shows that base-load power is to some extent an artificial construct. The quantity of base-load is not a fixed, fundamental characteristic of an electricity supply system. The important thing is to have a generating system that supplies clean, reliable electric power, while limiting wasteful demand growth. This can be achieved with a wide variety of generator types. Renewable energy, coupled with efficient energy use and backed up with gas power for a transitional period, can do the job.

Most electric power is used during the daytime, so daytime power (from intermediate-load and peak-load power stations) is at least as important as base-load. Even in the absence of cheap electrical storage, solar photovoltaic (PV) electricity will be able to make a large contribution to daytime power as its price declines in the future, as a result of expanding markets and ongoing technological improvements.

Fallacy 10: Renewable energy has huge land requirements

Wind and solar power generally have smaller land requirements than equivalent coal power with open-cut coalmines.

Wind power is normally installed on agricultural land, where its turbines and access roads occupy only 1–2 per cent of land area. The other 98–99 per cent of land can still be used for agriculture. To replace a 1000 megawatt coal-fired power station with wind power would require 6.5–15 square km of land actually occupied, depending upon wind speeds of the wind farm sites (see Appendix B). Typical open-cut coal mines occupy over 50 square km. Even underground coal mines, using longwall mining technologies, can damage large areas of land.

A square of area only 22.6 km x 22.6 km = 510 square km could supply all of Australia’s current electricity demand by converting solar energy at 20 per cent conversion efficiency *without concentrators*. With solar concentrators, a much smaller area would be required. The *residential* component of electricity demand could be supplied by covering on average about 28 square metres (5.3 m x 5.3 m) of rooftop space of each house with flat-plate solar PV modules. Thus, no additional land would be required for residential solar electricity and the land required for commercial and industrial uses of electricity would be only a few hundred square km. (See Appendix B for calculation.)

In practice, neither wind nor solar would supply all electricity, which would be provided by a broad mix of renewable sources.

Fallacy 11: Wind power has major adverse impacts on birds and biodiversity in general; noise is a major problem; wind power is inefficient; wind power causes bushfires; etc.

All these claims have been shown to be either untrue or grossly exaggerated (EWEA, 2003; Diesendorf, 2007a, chapter 6).

Fallacy 12: A sustainable energy solution is much more expensive than conventional coal power

As the ExternE studies (ExternE, 1998; Rabl and Spadaro, 2000) and Stern (2006) recognize, conventional coal power is very expensive in terms of economic, environmental and health impacts. The costs of drought, increasing prevalence and severity of bushfires, loss of tourism at snowfields and the Great Barrier Reef, and the impacts of rising sea-levels on urban infrastructure will be huge. But at present these costs are not included in the price of coal power in Australia. They are externalised. Carbon pricing, by means of a carbon tax or emissions trading, is a means of internalising some of these external costs.

Before a carbon price is implemented, all clean alternatives to conventional coal power (apart from energy efficiency) appear to be more expensive than dirty coal power. However, the combination of efficient energy use and renewable energy will be much less expensive than coal with CCS without energy efficiency. This is because the economic savings from efficient energy use can compensate for much of the additional costs of renewable energy. Another way of stating this is that, although the cost per kilowatt-hour of electricity will increase, the number of kilowatt-hours used will decline and so the total energy bill will not necessarily increase significantly.

If proponents of so-called ‘clean coal’ claim that they too can obtain the benefits of energy efficiency, it can be pointed out that energy efficiency has not been implemented to a significant degree with coal power. Indeed, one purpose of developing coal with CCS is to maintain endless growth in demand. Under these circumstances, it is unlikely that more than lip service will be paid to energy efficiency (the present situation).

Fallacy 13: Substituting energy efficiency (EE) and renewable energy (RE) for coal would lose jobs

To the contrary, EE and RE can provide several times more jobs per kilowatt-hour *in Australia* than coal (see also Section 4.5 and Table 1). This is because the smaller scale of sustainable energy technologies (compared with coal) lends itself to manufacture in Australia. For example, when a wind farm is built in Australia, over 50 per cent of the capital cost is spent in Australia. As the wind industry grows, the Australian content could grow to 75 per cent. Wind power currently employs in Australia 2–3 times the number of job-years per kilowatt-hour of coal power (including the associated coal mining), while bioelectricity employs 3.5 times (mostly in rural areas). Energy efficiency technologies and measures also employ several times more job-years.

As the result of automation, employment in coal mining has halved since 1986, even though the *amount* of coal mined has increased substantially (ABS data). When a coal-fired power station is built in Australia, only about 25 per cent of the capital cost is actually spent in Australia. Similarly, large coal-mining equipment, such as dredges for open-cut mining and longwall diggers for underground mining, is imported.

It is shown in Section 5.6 that the job losses from the Australian coal industry from a 25 per cent renewable energy target could be addressed by not replacing a small fraction of the workers who retire annually from the coal industry.

3. Greenhouse gas reduction scenarios for Australia to 2020

Having refuted some of the common fallacies about sustainable energy, this submission now summarises a recent greenhouse gas reduction scenario by Diesendorf (2007c). The study uses as a baseline the Australian Greenhouse Office's business-as-usual (BAU) 'with measures' scenario for the projected growth in CO_2-equivalent greenhouse gas emissions from 565 megatonnes (Mt) per annum in 2004 to 702 Mt per annum in 2020, an increase of 24 per cent (AGO, 2006).

Diesendorf (2007c) considers two principal scenarios for reversing this rapid projected growth in emissions. Scenario 1 introduces efficient energy use and low-temperature solar heat into the residential, commercial and industrial sectors and renewable energy (mostly wind power and bioelectricity pre-2020) into the electricity supply mix. It also expands cogeneration with natural gas and makes substantial reductions in fugitive emissions from coal and natural gas facilities. These measures are safe, available now and require no major technological breakthroughs. They could reduce AGO's projected 2020 CO_2-e emissions from 702 Mt to 480 Mt per annum, which is 13 per cent below the 1990 level.

To achieve further reductions in order to meet the target of a 30 per cent reduction below the 1990 level by 2020, Scenario 2 starts with the Scenario 1 measures and in addition addresses some of the driving forces behind BAU emissions growth, including Australia's principal energy-intensive industry (aluminium smelting), land clearing, diet and population growth. Also included are some promising technologies and measures, which, although only capable of minor contributions by 2020, could produce substantial additional reductions beyond 2020. These are solar and geothermal power, improvements in urban public transport and a partial shift to hybrid, plug-in hybrid and all-electric vehicles.

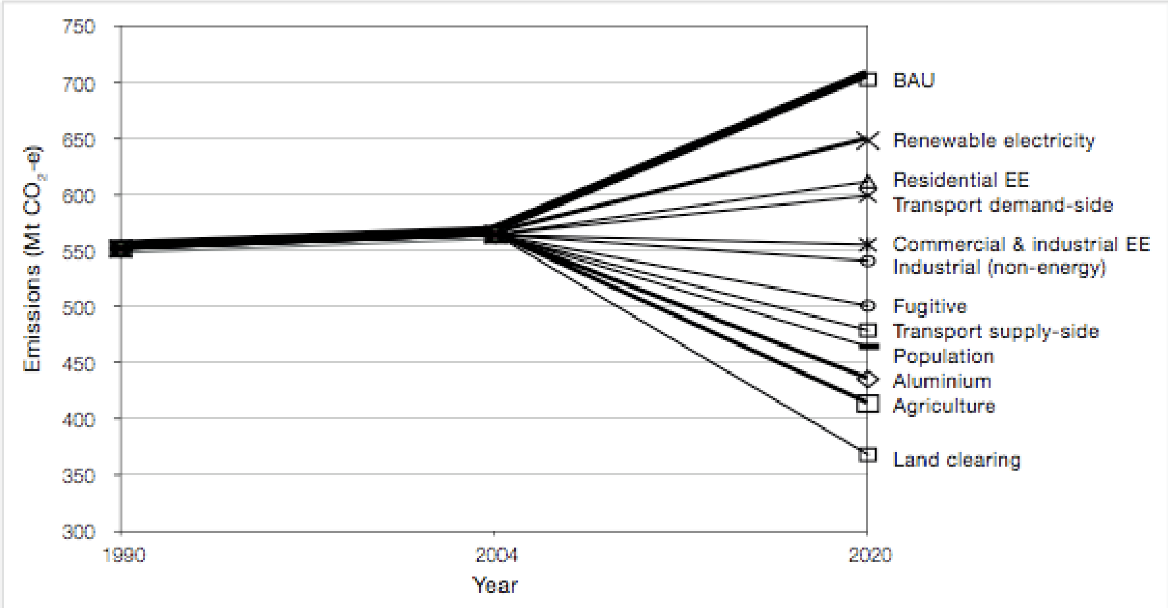
In total, the GHG abatement measures proposed in Scenario 2 of this study reduce annual CO_2-e emissions to 33 per cent below 1990 levels (to 372 Mt per annum) by 2020, a reduction of 330 Mt per annum from the BAU projection for 2020 (see Figure 1).

The largest wedge of reductions comprises renewable electricity with cogeneration (54 Mt per annum in 2020), followed by stopping land clearing and deforestation (45 Mt), commercial and industrial energy efficiency and solar heat (44 Mt), cutting fugitive emissions from oil, gas and coal production (40 Mt), and residential energy efficiency and solar hot water (36 Mt).

The report's results also highlight the importance of energy efficiency to any emissions reduction plan. If we combine the energy efficiency and solar heat measures from the residential, commercial and industrial sectors, then the total emission reductions (80 Mt) dwarf even the contribution from renewable electricity with cogeneration.

Although this study does not perform an economic analysis of these measures, it notes that energy efficiency measures are generally highly cost-effective. From a societal viewpoint, the economic savings arising from energy efficiency could offset a large fraction of the additional costs of renewable energy.

Figure 1: 'Wedges' of emission reduction obtained in Scenario 2 of Diesendorf (2007c)



Note: EE denotes energy efficiency.

This study confirms that there is no need to rely upon unproven, risky technologies with long development times, such as coal power with CO_2 capture and burial, or a nuclear power, which would ultimately become a significant CO_2 emitter as the limited reserves of high-grade uranium ore are used up.

The scenario study has not exhausted all clean and safe possibilities for reducing emissions, so additional measures may well be available. However, none of the wedges contributing to this target can be achieved without new policies by federal and state governments. Clearly, the pre-2008 policy neglect of energy efficiency, solar hot water, wind power, bioenergy, cogeneration, solar electricity, public transport and electric vehicles must be reversed. With government support for the development of the industry, market and technologies, these clean energy technologies could make an even greater contribution by 2020.

Based on the scenario analysis by Diesendorf (2007c), this submission recommends that Australia set a 2020 emissions reduction target of 30 per cent below the 1990 level, commence implementing policies in 2008 and aim to get the first absolute reductions in calendar year 2010.

4. Policies to disseminate sustainable energy

Having drawn attention to the urgent need for Australia to reduce greenhouse gas emissions substantially before 2020 and having presented a scenario that could achieve a reduction to 33 per cent below the 1990 level by 2020, the next step is to set out policies to achieve such a reduction. This section is summarised from Diesendorf (2007a, chapter 14) with some additional material.

The barriers to a sustainable solution are economic, cultural, economic, educational, regulatory, institutional and political. Some examples are:

- the notion that Australia can and should continue with endless growth in energy consumption;
- de facto subsidies to wasteful energy use, such as powerline upgrades and new power stations constructed to support air conditioning;
- fallacies about the alleged limitations of sustainable energy, discussed in Section 2;
- the notion that energy-intensive resource industries are the backbone of Australia's economy, when actually they contribute less than 10 per cent of GDP;
- subsidies to the production and use of fossil fuels, especially oil, amounting to over $10 billion per annum (Riedy & Diesendorf, 2003; Riedy, 2007);
- the failure so far to include the approximate costs of the environmental and health damage from fossil fuels in their respective prices;
- the failure to recognise that huge potential energy efficiency improvements are held back by market failures;
- biased government spending on infrastructure (e.g. roads generally receive 10 times federal government transport funding of rail);
- grossly inadequate government funding of R&D on sustainable energy pre-2008;
- the immense political power of the big greenhouse gas emitting industries (Pearse, 2007).

Clearly, with such a wide range of formidable barriers, there is no single magic bullet to drive the transition to a sustainable energy and transport future. Rather, there is a need for several different types of policy instrument to be implemented simultaneously to overcome different types of barrier and to complement one another. The main types of policy instrument are economic, regulatory, educational, institutional and community participation. All will be needed to make the transition to a sustainable energy future.

In particular, this submission rejects the notion that a carbon price alone is sufficient to achieve the environmental goal, for the following reasons:

- As a result of political pressures by vested interests, an emissions trading scheme (ETS) – discussed in Section 4.2.2 – could be set up in a manner that transfers windfall profits to big greenhouse gas emitters, without reducing emissions.

- Even if a potentially effective ETS is set up, political pressures could lead to such a low initial cap on emissions that the carbon price may take a decade or more to reach a sufficiently high level to produce a large enough change in the economic structure (including the energy supply system) to reduce Australia's greenhouse gas emissions substantially. However, government measures – such as an expanded MRET, a ban on conventional coal-fired power stations, R&D grants, rebates on the capital cost of residential and commercial PV systems, and funding for improvements in urban and intercity rail – could be implemented almost immediately.

- Even a working, comprehensive ETS or other form of carbon pricing will have little impact on efficient energy use and other technologies or measures that are subject to market failure. Furthermore, carbon pricing is likely to be too low for the foreseeable future to assist technologies that are currently very expensive while having huge potential: e.g. solar electricity.

4.1 Policies for efficient energy use

There are a wide variety of cost-effective measures to implement substantial amounts of efficiency in energy use, however their dissemination is impeded by market failure. Therefore, this is an area where regulation must play an important role. The following measures are recommended:

- *Mandatory energy rating and labelling of all new and existing buildings and all new energy-using appliances and equipment.*
  Energy labelling of buildings must be disclosed whenever the building is put onto the market or leased, as in the Australian Capital Territory. However, this should not just cover the heating and cooling energy, but also the energy efficiency of major fixed appliances within the building such as water heaters, cooking stoves, air conditioners and lighting.

- *Mandatory energy performance standards should be phased in for buildings, commencing with all rental and Government-owned and Government-leased buildings.* Existing buildings would be required to achieve less stringent energy ratings than new buildings. There would be government assistance, for example, in the form of grants and low-interest loans, to low-income building owners, such as pensioners, who are landlords.

- *The NSW BASIX and similar schemes in other States should be expanded* to include mandatory energy performance standards for all building renovations. Extensions should meet existing performance standards, while the older existing parts of renovated buildings should be required to be upgraded to a lesser extent, compatible with what that is practicable and reasonable when renovating.

- *Mandatory energy performance standards for all new energy-using appliances and equipment.*
  Current standards are limited to only a few appliances.

- *Remove constraints on residential solar*
  State Governments should make it illegal for local government, developers or the body corporate of residences under strata title to ban solar powered equipment such as solar water heaters, photovoltaic power systems, or solar clothes driers (that is, clothes lines). This should also apply to developers' covenants. Local governments should not be allowed to require planning permission for solar hot water.

- *Inverted electricity tariffs* (that is, the more you use, the cheaper the price of a unit of electricity) should be banned by State Governments. A variation of such greenhouse-unfriendly tariffs is the practice of some energy retailers of charging customers, who have a small to average energy consumption, *a large fixed component of the bill* and a small variable component. This practice should be regulated. In the interests of energy conservation it is important that the largest component of the bill be the variable charge and that this be proportional to energy consumed. Indeed, for very large consumptions, the unit price should be stepped up.

- *Local governmnent's role:*
  In cases where State Governments are slow to strengthen energy performance standards for new buildings and extensions, local governments can and should act. Leichhardt Council in Sydney took the initiative by requiring solar hot water (or gas, if the roof was shaded) on all new houses and extensions requiring hot water.

- State Governments should establish a *Clean Energy Fund or Demand Management Fund* to provide incentives and resources to overcome barriers to efficient energy use to accelerate the adoption of energy efficiency in homes and businesses. The fund should be set at a reasonable level (no less than 1% of total energy bills) and be made independent of the State budget, by being raised directly from electricity bills. The NSW Government has established a high level taskforce to report on creating such a Demand Management Fund.

- *Energy Performance Contracting* has been operating for years in Australia, mainly for large industrial and commercial energy consumers. State Governments could assist in extending this process to a large number of smaller energy consumers by providing support for the development of project aggregation by performance contractors, thus reducing the transaction costs of capturing energy opportunities in homes and small business.

- Alternatively, as an extension of the water saving scheme being run by Sydney Water, State Governments or energy retailers could offer householders a *package of low-cost energy efficiency measures* for energy-using appliances and equipment that are not part of the building envelope. The package could include compact fluorescent lamps, water efficient shower-heads and tap fittings, insulation wrap and adjustment of thermostat on hot water systems, and, for old refrigerators, replacement of door seals and possibly compressors. This package would include a service-call by an electrician-plumber. If implemented on a mass scale, the cost per household would be low, the reductions in energy consumption and CO_2 emissions would be significant and so would the reductions in energy and water bills. Thus the scheme would be attractive to many households. This proposal would have value both by reducing greenhouse gas emissions and by educating the community about simple energy efficiency measures in the home. The service could be provided free of charge to low income earners, funded out of a small part of the revenue from carbon pricing.

4.2 Carbon pricing

4.2.1 Carbon tax

A tax has several advantages over other market mechanisms, such as emission trading.

- Taxes are a well-known instrument that can be readily implemented through the existing administrative system. They are generally less complicated and less expensive to administer than emissions trading.

- Although emissions trading provides a precise reduction in emissions, provided it is properly structured and controlled, a tax is generally preferred by the economic portfolios of government, because its effect on the budget is clear-cut.

- Revenues from taxes (and from types of emission trading that involve auctioning of permits) can fund compensation for low-income families that are vulnerable to higher energy prices, adjustment assistance for fossil fuel-producing communities and development of low-emission technologies and infrastructure.

Carbon taxes vary according to the size of tax, the greenhouse gases taxed and the exemptions or concessions granted to various stakeholders, especially large energy-intensive industries. In the energy sector, a tax on CO_2 emissions puts the biggest price increase on the most greenhouse polluting fossil fuel, coal, and the smallest price increase on the cleanest (in greenhouse terms) fossil fuel, gas. Most forms of renewable energy have very low fossil fuel inputs and hence very low CO_2 emissions, and so no carbon tax would be payable. The main exceptions are the particular hydro-electric schemes that flood extensive vegetated valleys and some forms of bioenergy that have large inputs of fossil energy via processing, fertiliser and transportation over long distances.

While a carbon tax is a simple and inexpensive instrument for exposing consumers to more realistic prices of using fossil fuels and products made with fossil fuels, it is not sufficient on its own to drive the transition to sustainable energy. The alternatives and infrastructure must be put in place, actions that require a whole range of other policy instruments as well. Otherwise consumers just have to pay the tax without making any change in behaviour.

In the late 1990s, a number of European countries had various forms of carbon and/or energy tax, with various exemptions, concessions and rebates for large industries. In some of these countires, taxes were superseded by the introduction of the European Union emissions trading scheme on 1 January 2005. Other countries, such as in Germany, continued, on the basis that carbon taxes with industry exemptions are mainly paid by households, while emission permits are only applied to industries (although they are ultimately paid for by consumers of the products made by the industries).

Opposition to carbon taxes in Australia comes primarily from the big greenhouse gas producers – fossil fuel industries, aluminium, cement and steel – and the motor vehicle industry. The main argument used by opponents is that a tax would damage international competitiveness and therefore jobs. However, this objection is readily overcome by means of border adjustments, as discussed in Subsection 4.2.4.

4.2.2 Emissions trading

Emissions trading is much more complicated than a tax. It involves setting a target of permitted emissions, allocating permits to producers (either direct or indirect) of the emissions, while ensuring that the total number of permits is consistent with the target, and then mandating that producers of emissions acquire sufficient permits to cover their emissions. Participants in the market may trade the permits. Then, in theory, participants who can reduce their emissions at low cost will sell some of their permits to participants who can only reduce their emissions at high cost. Thus, the lowest cost measures for reducing emissions will tend to be implemented first, buying time for those with high-cost measures to change their practices.

The basic requirements of a successful emissions trading scheme are a tradeable commodity, willing buyers and willing sellers. To obtain willing buyers it is essential to make participation mandatory for some sections of the economy. So, despite the rhetoric of emissions trading being a purely market mechanism, it also requires a strong regulatory component. Willing sellers will come forward when the target and allocation of emission permits encourages them to do so.

In practice there are many ways of designing and implementing emissions trading. Important choices have to be made between schemes that:

- reduce emissions that can be physically measured, or include 'reductions' that are uncertain and estimated;
- allocate emission permits free of charge to emitting industries in proportion to their current emissions ('grandfathering'), or auction permits with all comers entitled to bid;
- define the liable parties (those that have to obtain the emission permits) to be the relatively small number of industries that actually produce the emissions directly, or the vast numbers of consumers who produce the emissions indirectly through their purchases of good and services;
- focus on CO_2 emissions alone, or also include several other greenhouse gases with emissions measured in CO_2-equivalents.

This flexibility offers both opportunities and risks. These schemes and their rules are created by governments or international organisations, who can shape them for political purposes, responding to pressures from powerful stakeholders. Furthermore, some versions of these schemes suffer inherently from market failures and they all feed into energy markets that have their own market failures. So, the design, regulation, enforcement and transparency of emission trading schemes are crucial to their success in reducing emissions.

There are two major types of emission trading schemes: *cap and trade* (for example, the European Union's emission trading scheme) and *baseline and credit* (for example, the NSW Greenhouse Gas Abatement Scheme).

Baseline and credit schemes give credit to reductions relative to a projected future 'baseline' growth in emissions that in practice can become identical with Business-As-Usual, that is, the expected growth in emissions in the absence of the scheme. With this approach there is no guarantee that emissions will ever be reduced in absolute terms. In the NSW scheme, over 95% of abatement certificates registered in 2003 appear to have come from installations that were built or committed well prior to the commencement of the scheme (Betz & MacGill, 2005). Beneficiaries of windfall payments include coal-fired power stations in NSW and Victoria that have slightly reduced their enormous CO_2 emissions by means of small improvements in the efficiency of energy generation that arguably they would have made anyway. In a truly greenhouse-constrained energy system, there would be very few if any conventional coal-fired power stations. Therefore, it is wasteful to construct a scheme that funds minor improvements to a technology that is the major part of the problem.

In contrast, cap and trade schemes place firm limits on total emissions in future years. If they are well designed, operated and regulated, they only issue sufficient permits to reach that limit. However, several countries in the European Union's emission trading scheme have initially allocated initially more permits than are necessary to cover their emissions. There is an opportunity to rectify such errors in the second phase of the scheme. To drive a rapid reduction in emissions, the size of the cap can be reduced by revaluing existing permits at regular intervals.

Allocating emission permits by grandfathering gives an advantage to existing industries, many of which are big greenhouse gas polluters, and makes it more difficult for new cleaner technologies to enter the market. Thus innovation is undermined. As experience in Phase 1 of the European ETS has shown, grandfathering hands windfall profits to the big GHG emitters. It would be far better for government to receive this revenue and use part of it to assist low-income earners to reduce their emissions and the remainder to fund programs to assist the transition to sustainable energy and public transport.

On the other hand, commencing emissions trading with a system that allocates all permits by auction could lead to stranded assets, allegedly causing the existing providers of energy and greenhouse-intensive products to suffer big economic losses. In practice, the additional costs of greenhouse-intensive products will be passed on to consumers and there is no general case for compensating the producers of the products. The only businesses that actually need special consideration are those whose exports are competing with overseas suppliers who are not subject to carbon pricing and those whose products are competing with imports from suppliers who are not subject to carbon pricing (see Subsection 4.2.4).

Making the liable parties the big greenhouse gas emitting industries is simpler to administer than making all consumers liable and allocating permits to each person. However, the latter approach has the advantage of engaging everyone actively in a valuable community education process. In 2006, the British Government was considering a scheme in which everyone would receive a kind of 'credit card' with an emissions allowance. In purchasing something, the consumer would have to pay in both money and emissions.

More detailed discussion of emissions trading schemes is given by the Australian Greenhouse Office (1999), Betz and MacGill (2005) and Climate Strategies (web site).

There are similarities and differences between carbon taxes and emission trading. In particular, cap and trade schemes applied to emitting industries with auctioned permits become essentially a tax on most participants in energy markets. However, a carbon tax is administratively much simpler than any emissions trading scheme.

According to economic theory, in a perfect market a carbon tax or a well-designed emissions trading scheme is the only market instrument required to set in place an emissions reduction program. In practice, markets are imperfect and there will be strong pressures from business and voters to phase in such schemes slowly, to avoid sudden shocks to business and the community. Therefore it is likely that carbon taxes and emission permit schemes may not be implemented for several years in Australia. Once a scheme is established, the initial carbon prices may be too small to drive a rapid transition to an energy system based on renewable energy and cleaner fossil fuel technologies. Also, some renewable energy technologies with huge potential, such as solar electricity, may still be too expensive to become economically competitive for a decade or two, even with a carbon price. For these reasons, additional market and non-market mechanisms will be needed, at least in the short-term. Two key transitional mechanisms are an expansion and time-extension of the Mandatory Renewable Energy Target (MRET) and the imposition of severe limits on the greenhouse intensities of new fossil-fuelled power stations.

4.2.3 Tax or ETS?

The whole purpose of carbon pricing must be to reduce greenhouse gas emissions by changing the economic structure to one that is much less greenhouse-intensive. It would be a waste of time and money to set up a carbon pricing system that is either ineffective or too slow. The only effective options are either a carbon tax or an ETS with the following properties:

- a tight initial cap on emissions, with the cap being progressively tightened every three years or less;
- allocation of all emission permits by auction at the outset;
- emission permits *not* to be permanent property rights;
- no exemptions for greenhouse-intensive industries, apart from border adjustments, as discussed in 4.2.4;
- no 'safety valve' to limit the carbon price.

Because there are so many ways to subvert the effectiveness of an ETS, this submission favours a carbon tax, with appropriate measures to assist low-income earners to save energy and thus stabilise their energy bills.

4.2.4 Resolving the international competitiveness objection to carbon pricing

Pre-2008, the Coalition Government attempted to justify its refusal to ratify the Kyoto Protocol on the grounds that it would damage the Australian economy, which it described as highly 'fossil fuel dependent' compared with most other economies. In particular, the Coalition claimed that a carbon tax or emissions trading would raise the price of energy for Australia's emissions intensive industries to such an extent that they would no longer be internationally competitive. As a result, some industries would fail, while others would move overseas, where they may actually increase their greenhouse gas emissions. A paper from the Australia Institute has analysed this issue (Saddler, Muller and Cuevas, 2006). It argues that a company may be disadvantaged in international trade by the imposition of a carbon tax or an emissions trading scheme, when *all* of the following three conditions hold:

- the industry is particularly emissions intensive;
- the industry is particularly trade exposed (either competing in export markets or with imports in the domestic Australian market);
- this trade exposure is to competition with countries that do not have to meet emissions caps under the Kyoto Protocol (that is, the USA and developing countries).

The analysis shows that there would be very small impacts of carbon pricing on most sectors of the Australian economy. The vulnerable exports include alumina, aluminium, other non-ferrous metals, steel, liquefied natural gas and gold. Less than half of these exports go to developing countries. For imports, only steel and oil refining would suffer significant competitive disadvantage. In total, the industries affected comprise only 1.5% of GDP and 19% of merchandise exports.

The paper recommends that Australia ratify the Kyoto Protocol and implement either a carbon tax or an ETS. It examines several options for dealing with the competitiveness problem: wholesale exemptions, negotiated agreements, offsetting tax deductions and financial incentives for energy efficiency improvements. It makes the case that the best and fairest way to assist the disadvantaged industries, while maintaining the carbon price signal within the domestic economy, is to apply a *border tax adjustment*. This means that a rebate would be paid to, for example, aluminium exporters, to offset the increase in production costs caused by the tax or scheme. But, the rebate would only be paid for the exported product – aluminium consumed domestically would be subject to the carbon price signal. Conversely, a levy could be applied to emissions intensive imports to offset any significant carbon price disadvantage faced by competing local producers.

Border tax adjustments are already established in a number of tax systems, including Australia's GST and the European value added tax. The USA has used it for several environmental taxes and the Superfund chemical excises.

While there is a case for protecting the international competitiveness of industries that are disadvantaged by market mechanisms of emission reduction, there can be no justification for protecting emissions intensive industries from competition by cleaner industries within the domestic economy. The whole purpose of a well designed carbon tax or tradeable emissions scheme is to increase significantly the prices of emissions intensive goods and services and thus advantage low emission goods and services. Since the economy (and population) drive energy use and hence emissions, such a change is essential for obtaining large reductions in emissions. This outcome cannot be achieved simply by making existing production processes more energy efficient and making small changes to existing energy supply technologies. A genuine change in the economic structure of the nation is needed.

4.3 Greenhouse gas intensity constraint on new power stations

Conventional (pulverised fuel) power stations burning black coal have greenhouse gas emission intensities typically in the range 0.8–1.0 tonnes CO_2 per MWh of electricity sent out, depending upon age, choice of technology, quality of coal, capacity, etc. The low end of the range could possibly be achieved by new power stations with supercritical boilers[2], but even these still have emission intensities double those of new combined cycle gas-fired power stations. Clearly the use of conventional coal-fired power stations as major sources of electricity is incompatible with the goal of achieving large reductions in CO_2 emissions. In eastern Australia, these power stations currently generate electricity at levelised prices in the range 3.5–4.0 c/kWh. These prices do not reflect the substantial environmental and health damage produced by coal-fired power stations.

It is proposed that the initial allowable intensity for new power stations in all States should be 0.5 tonnes CO_2/MWh sent out and then 0.1 tonnes CO_2/MWh after 2020. This would entail that from 2008 until 2020 the only power stations that would be built would be either renewable energy or gas-fired combined cycle or cogeneration plants. Beyond 2020 the only power stations that would be built would be either renewable energy or fossil fuels with

[2] In the new Queensland coal power station, Millmerran, the greenhouse intensity advantage of the supercritical boiler is offset to some extent by the additional energy consumption from air cooling.

geosequestration (assuming that geosequestration proves to be permanent, safe, cost-effective compared with renewable energy, suitable for the location in question, etc.).

For existing coal-fired power stations, a phased reduction in emission intensities is recommended to 0.7 tonnes CO_2/MWh of electricity sent out after 2012, then to 0.6 after 2017 and 0.5 after 2022. For existing power stations, but not for new ones, it would permissible to achieve all or part of these reductions by installing renewable energy and cogeneration plants as offsets.

The Federal Government should immediately include a 'greenhouse trigger' in the Environmental Protection and Biodiversity Conservation (EPBC) Act 1999 leading to assessment of proposals generating more than 0.5 Mt of greenhouse gas emissions per year.

4.4 Mandatory Renewable Energy Target

Until 2006, MRET was successful in boosting the hydro-electricity, wind power and solar hot water industries in Australia, but has not assisted significantly bioelectricity or solar electricity, which are currently more expensive. By mid-2006, sufficient renewable energy had been installed to meet the tiny target for 2010. As a result the market price of Renewable Energy Certificates (RECs) dropped and then the wind power industry experienced the shock of a sudden transition from boom to bust, with cancellations of wind farm proposals and the shutdown of two factories manufacturing wind turbine components. At least 5 gigawatts (GW) of proposed wind farms, many of which have already been approved, are now unlikely to proceed until the new Labor Government implements its 20 per cent renewable energy target for 2020.

This new target is an election promise, which (unlike carbon pricing) is not subject to conditions. Therefore, it should be implemented immediately and not delayed until the outcome of the Garnaut review. This author believes that the target should be increased to 25 per cent for 2020, a level that is achievable with existing technologies (Diesendorf, 2007c). Australia needs to build up its wind power and bioelectricity industries now. Until a substantial carbon tax or emissions trading system is operating, with a carbon price that is sufficiently high to permit the lower cost renewable sources of electricity to compete with conventional coal power, MRET will be needed.

To assist wind power in the southern States, a carbon price of at least $35/tonne CO_2 is required. To assist some forms of bioelectricity from the residues of existing crops and plantation forests, a carbon price of at least $40/tonne is required – $60/tonne would encourage a much larger contribution from bioelectricity.

4.5 Addressing social impacts of carbon pricing

A key component of sustainable development is social equity, which means equal opportunity for all in terms of accessing basic needs. From this perspective, concern for the impact of carbon pricing on the international competitiveness of a few 'Australian' industries may be justified by the potential job losses that would occur in the absence of an offset, such as border adjustment. In addition social equity demands that job losses in greenhouse gas emitting industries that are not trade-exposed be managed fairly with adjustment or transition packages and the creation of new jobs. Adjustment packages can be funded out of a small part of the revenue from carbon pricing. The number of new local (that is, within Australia) jobs that would be created by clean energy technologies is likely to be much higher than those lost by emission intensive industries.

Table 1 compares direct employment within Australia in the manufacture, construction and operation of a coal-fired power station and associated coal-mine, a biomass cogeneration plant and a wind farm, each commissioned in Australia since 2000. More recently commissioned wind farms have a much higher Australian content than 44 per cent and it seems likely that, if the industry continues to expand in Australia, it may be possible to manufacture most of the components in Australia, reaching an Australian content of about 75 per cent and providing 3–5 times more local jobs per kilowatt-hour than coal-fired electricity. Bioelectricity, generated from many small power stations dotted over the wheat, sugar and plantation forest areas, could greatly increase the number of *rural* jobs. State and Federal Governments could offer incentives to clean energy industries to locate their factories and offices in former coal mining areas. Implementation of efficient energy use could employ many more electricians, plumbers, metal-workers and engineers.

Table 1
Case studies of total Australian employment for different types of base-load power station

Power station (name)	Description	Australian content (% of cost)	Total Australian employment (job-yr/TWh)
Tarong North	Coal-fired, rated 450 MW	26	49
Albany wind farm	Wind farm, rated 21.6 MW	44	120
Rocky Point sugar mill	Cogeneration, rated 30 MW, fuel: bagasse + wood waste	50	220

Source: MacGill, Watt & Passey (2002); Diesendorf (2004)

Some economists claim that the reason why wind power and bioenergy create more *local* jobs is because they are somehow ‘less economically efficient’ than coal power. The real reason is that wind power and bioenergy have much greater Australian content. This in turn is a result of the scale and location of the technologies. Of course, to investigate the employment impact of a change in the energy mix on the Australian economy as a whole is a more complex task, the domain of macroeconomic models.

Social equity also demands that we create policies to help low-income earners to adjust to the higher energy prices that would follow from carbon pricing. In terms of reducing GHG emissions, the best way of doing this is for governments to implement policies to reduce substantially energy waste through programs to improve efficient energy use, especially of buildings, with the early action on all rented residential buildings and assistance programs for housing owned by low-income earners. Another means of assisting low-income earners is to integrate urban planning with improved public transport. Several studies conducted to date reveal a huge potential for saving energy and money from efficient energy use. Improvements in public transport infrastructure and service delivery can also produce long-term improvements in the economics of operating a city. For individuals, increases in the prices of a kilowatt-hour of electricity, a megajoule of gas and a litre of petrol would be balanced by reductions in the numbers of kilowatt-hours, megajoules and litres used. With well-designed programs for energy efficiency and urban infrastructure, consumers’ bills need not increase significantly.

Parts of these programs will entail increased expenditure on the part of governments, especially for expanding public transport and retrofitting homes owned by low-income earners. This expenditure could be met from the revenue that governments would raise from either a carbon tax or from the auctioning of emissions permits. Naturally there will have to be negotiations between the three levels of government on the allocation of monies, however the revenue could be enormous. For annual CO_2 emissions of 400 million tonnes (Mt) at a carbon price of $40 per tonne, annual revenue would be $16 billion. Billions more would be available from the removal of subsidies to the production and use of fossil fuels.

4.6 Removal of perverse subsidies and perverse energy tariffs

The implementation of a carbon tax or emission permits should be combined with the phase-out of the perverse subsidies to the production and use of fossil fuels, mentioned above. Politically, this will be difficult in some cases, because certain subsidies (for example, tax concessions for company cars) have almost become part of the Australian ‘culture’, while others (for example, subsidised electricity to aluminium smelters) are subject to long-term contracts with industry and are built into the nation’s economic structure to the extent that their removal could leave a government open to the charge of being ‘anti-business’.

Covering business risk is an increasingly prevalent subsidy to fossil fuels. With an informed public, it should easier politically for governments to avoid taking on the financial and economic risk of new coal-fired power stations and motorways. With Australia planning to adopt emissions trading, there is a strong case for leaving this risk with private investors.

Despite the restructuring of the electricity industry in the 1990s, there are still subsidies and cross-subsidies on electricity prices that encourage an increase in greenhouse gas emissions. Residents and industries located in rural areas are charged for electricity from the grid according ‘postage stamp’ prices that are independent of location. This means that they receive a cross-subsidy from urban electricity users on grid electricity, while they do not receive equivalent subsidies for implementing efficient energy use or renewable energy. This drives an increase in purchases of coal-fired electricity supply from the grid. On the principle that rural electricity users should have freedom of choice in how they spend their subsidy, it is proposed here that state governments switch the subsidies away from electricity rates to direct monetary payments and assistance programs to improve energy efficiency and install solar hot water. Then the market can operate to permit energy efficiency, solar hot water and renewable energy to compete in rural areas where they are generally most cost-effective.

Another perverse type of pricing is the high fixed charges, combined with low energy charges, that some electricity retailers impose. Since this encourages increased consumption, it should be regulated.

Other huge subsidies to the production and use of fossil fuels in Australia could amount to over $9 billion per year (Riedy, 2007; Riedy & Diesendorf, 2003). The major part of these subsidies is ‘perverse’ in the sense that it is both economically inefficient and environmentally damaging. Most of the subsidies go to liquid fuels and the use of motor vehicles. However, in several States there are large subsidies to aluminium smelting (Turton, 2002) and in every State there is a large de facto cross-subsidy to the use of air conditioning, the use of which is rising rapidly in Australia. When someone purchases and uses an air conditioner, all electricity users in the State have to pay for the costs of the additional infrastructure required: peak-load power stations and power lines. Rough estimates suggest that, for a single-phase 5 kW residential air conditioner, the real costs could be of the order of $1500 per annum over a 10-year simple payback period. However, at present the customer may be paying only $60 per annum (ABCSE, 2003).

4.7 Research, development, demonstration and commercialisation

There is a widespread misconception that R&D is limited to an early phase of new technologies. In reality, it is needed both to promote innovation and to support and improve existing commercially available technologies.

Up to the end of 2007 funding for research, development, demonstration and commercialisation for sustainable energy has been very low in Australia and needs to be increased substantially. Of the little funding that is at present available for energy, the lion's share is going to fossil fuels. For example, there are three Cooperative Research Centres for fossil fuels but none for renewable energy and energy efficiency.

A small economy like Australia should avoid duplicating R&D on huge projects that is already being undertaken by the big economies, such as USA, EU, Russia and Japan. The Australian Government should resist pressures for Australia to spend hundreds of millions of dollars or more in prototype coal-fired power stations with geosequestration, or a contribution to the US$14 billion ITER nuclear fusion project.

Australian R & D funding could be used much more effectively to improve efficient energy use technologies and processes, solar industrial heat, solar electricity (where Australian researchers are world leaders), conversion processes for Australian biomass (especially second generation biofuels), and marine sources of power. In addition to energy technologies, there are many energy-intensive products and processes that need modest levels of funding for R&D leading to their substitution with low-carbon materials and production processes. A possible example would be improving and testing Eco-cement, an Australian-made prototype product that absorbs CO_2 from the atmosphere as it sets and hardens (TecEco website).

The private sector has a potentially important role in technology development and innovation. However, many technologies and innovations for greenhouse mitigation need investments over longer time periods than business will undertake, and so governments must provide incentives (for example, grants, tax deductions and procurement by government) and set up partnerships with industry.

To build a workforce capable of innovation, governments must provide sufficient funding for university education (both disciplinary and interdisciplinary) and technical training. Another essential element in an effective innovation policy is a long-term commitment by government to carbon pricing.

4.8 Policies for specific technologies

In addition to the general policies discussed above, several specific technologies require specific policies, such as:

- Modification of the electricity transmission and distribution systems to facilitate the integration of distributed sources – such as wind power, bioelectricity and solar power stations – into the grid. Particular government investments that are needed urgently are to strengthen the transmission links between SA and NSW (Murraylink) and between SA and Vic.

- Special feed-in tariffs for renewable sources with large potential, that are currently too expensive to benefit from MRET or carbon pricing. An example is solar thermal power stations, which can provide base-load power with low-cost thermal storage.

- Since residential and commercial photovoltaic systems compete with the *retail* price of electricity, a rebate would be more cost-effective than a feed-in tariff[3]. The previous Coalition Government's $8000 rebate should be extended to cover a much larger number of households, say 200,000 instead of 20,000 over 5 years.

- The Federal Government should fund the development of a national bioenergy roadmap for Australia.

- State and/or Federal Governments should introduce Biomass Establishment Grants for growing energy crops. In addition, they should develop a set of agreed contributions from governments to farmers for the planting of energy and other crops that would assist in limiting dryland salinity, erosion and other forms of land degradation.

- State or Federal Governments, whichever is funding farmers for growing crops for bioenergy and land remediation, should set up organisations to ensure that biomass production is ecologically sustainable – for example, that perennial grasses are grown on erosion-prone land that is unsuitable for annual food crops – and that biofuel quality meets standards.

- Federal transport funding should be modelled on the US Transport Equity Act (TEA-21), in which there are no longer guaranteed road funds, but rather a transparent process under which States, cities and local government areas must evaluate different transport options before funds are assigned to them from the Federal sphere. This results in rail and public transport receiving a similar share of federal transport funding to roads.

- Intercity rail tracks, especially those between Sydney, Melbourne and Brisbane, should be upgraded to allow high-speed passenger and freight services. To allow rail to compete on an equal basis with roads for interstate and intrastate freight transport, mass-distance charges should be introduced for heavy trucks, as in New Zealand and other countries.

[3] Unless the feed-in tariff is very high, as in Germany, there would be no incentive for residential and commercial electricity users to install sufficient PV modules to feed significant quantities of electricity into the grid.

5. Economic aspects and targets

5.1 Introducing risk into cost-benefit analysis of greenhouse mitigation

Cost-benefit analysis (CBA) is one of the principal inputs to political decision-making and so is likely to be one of the conceptual frameworks used in the Garnaut review. But, a fundamental problem of applying cost-benefit analysis to decisions about GHG mitigation is that it must weigh up different categories of things – in particular, costs with risks of certain types and magnitudes, against benefits with risks of different types and magnitudes. If risks are ignored, CBA is like comparing apples and shoes.

For example, consider the key problem of determining how fast Australia's greenhouse gas emissions should be reduced. Given Labor's long-term target of a 60 per cent reduction in greenhouse gas emissions below the 2000 level by 2050, what interim targets should be set for 2010, 2015, 2020 and 2030?

If the new government wishes to avoid rapid changes in the economic structure, it will set weak early targets, thus avoiding the political risk of upsetting the powerful industries that are the biggest greenhouse gas emitters: coal, oil, aluminium, steel, cement and motor vehicles. However, weak early targets (if adopted by other developed countries too) will expose the planet to the risk of the rapid amplification of global warming[4]. If this is observed, Australia and other countries may have to respond with sudden changes to their economic structures (say, in 2020) that would impose much larger economic costs than if they had commenced with stronger early targets and had tightened them progressively.

If, on the other hand, the Labor government commences with very strong early targets, it will (if other developed countries set similar targets) reduce the risk of the rapid amplification of climate change, while increasing the costs resulting from prematurely retiring existing plant. This in turn will increase the prices of energy and energy-consuming products and will increase the political risk of an anti-government campaign by the big greenhouse gas emitters.

If the economics is done by blithely ignoring the different risks, there will be an intermediate rate of emissions reduction that minimizes the annual cost of reduction. However, ignoring risks, which are fundamental to the whole issue of greenhouse mitigation, is invalid. Bearing in mind that some of the risks cannot be quantified, there is no mathematical solution to the problem of determining the optimal rate of emissions reduction. However, there are some recommendations that can be made on the basis of commonsense. These lead to a GHG reduction target.

5.2 Recommended GHG reduction target

Firstly, there is no rational justification for delaying the implementation of an emissions trading scheme (ETS) until 2010. Delays will only increase the risk of rapid amplification of global warming, with no benefit. Most of the groundwork for an Australian ETS has already been done, commencing around 1999 (Australian Greenhouse Office, 1999), and the

[4] Since some amplification is already occurring, policies can initially only slow amplification rather than eliminate it.

successes and failures of the first phase of the European Union's ETS can be quickly observed and learned from (Betz & Sato, 2006; Schleich, Betz & Rogge, 2007). An Australian ETS could and should be implemented to commence on 1 January 2009.

Secondly, there is no rational justification for commencing an ETS with a short-term emissions target that is too weak to produce a carbon price that makes combined-cycle natural gas power stations and the lowest cost renewable energy sources (solar hot water, wind power and some forms of bioelectricity) competitive with dirty coal power. The construction of new conventional coal-fired power stations must be terminated immediately, or the problem of achieving large reductions in the future will be exacerbated. With limited gas reserves and big export commitments for LNG from the North-West Shelf, Australia will need renewable energy to reach a significant reduction target which must be maintained and tightened it as time goes on. This could be achieved with an initial carbon price of $40 per tonne of CO_2, rising to $60 per tonne by 2020.

If a carbon tax is implemented, the carbon price is applied directly in the tax. Then, provided the government puts in place the appropriate policies for infrastructure, regulations and standards, educational programs, R&D and institutional change as discussed in Section 4, emission reductions will be achieved. However, the exact magnitudes of the emission reductions over time will depend upon the effectiveness of the implementation of the other policies. A tax alone will not be sufficient to achieve big reductions in emissions.

If an ETS is implemented instead of a carbon tax, then the emissions reductions will specified for future years, but there will be uncertainty in the future prices of emission permits. These prices will be affected by other policies implemented by the government to facilitate the widespread dissemination of, for example, energy efficiency, solar hot water, public transport, and electricity transmission lines from distributed sites. Since several of the policies recommended in Section 4 have low or no economic costs, they will assist in reducing the prices of emissions permits.

Based on his recent scenario study (Diesendorf, 2007c) and the above discussion, the present author recommends that the Australian Government:

- set a 2020 emissions reduction target of 30 per cent below the 1990 level;
- tighten the 2050 target to 80 per cent below the 1990 level;
- commence implementing low-cost policies (e.g. expansion of MRET; renewable energy and public transport grants; apply EPBC Act to ban new conventional coal power) in 2008;
- commence the ETS on 1 January 2009; and
- plan to achieve the first absolute reductions in greenhouse gas emissions in calendar year 2010.

5.3 Economics of sustainable energy scenarios

The essence is that the large economic savings from efficient energy use pay for a large part of the additional costs of renewable energy. For energy users in the residential, commercial and some small industrial sectors, efficient energy use substitutes for the *retail* price of energy. For electricity consumers in the residential and commercial sectors, retail prices are generally 3–4 times wholesale prices. Hence a saving of 20 per cent in energy consumption can reduce energy bills by much greater amounts, provided the fixed (supply) charge is capped.

Large industrial users of electricity generally purchase directly from the high-voltage transmission system, thus saving the costs of low-voltage distribution. In addition, some large industrial users (e.g. aluminium smelters) receive big subsidies on electricity prices. The result is that large industrial users of electricity receive lower benefits from energy efficiency than residential and commercial users. The removal of their subsidies and the implementation of carbon pricing would encourage improvements in industrial energy efficiency.

To tighten the economic case for sustainable energy, we now refute the claims of some economists that energy efficiency is unimportant. These claims are based on two arguments:
(1) The rebound effect cancels energy efficiency.
(2) Macroeconomic models show that energy efficiency is unimportant.

5.4 The rebound effect

This effect arises from the situation that people or organisations that save energy generally save money as a result. Then it is assumed that they spend all or most of the saved money on products that increase energy consumption again. The mental image is created of a rubber ball that is dropped and rebounds back to the same height at which it is released.

In reality, the size of the rebound depends on whether the money is invested in energy wasting (for example, a plasma TV) or energy saving (for example, a new 5-star refrigerator to replace an old 2-star) products and services. On average we would expect that people would spend the money in the same proportion as energy's proportion of GDP, about 8%. This is quite a small rebound. It becomes even smaller when we take into account that the energy efficiency of several appliances and energy-using equipments is improving[5]. This trend could be made much more definite and rapid by introducing government policies to promote energy efficiency through mandatory energy performance standards, energy audits and labelling, carbon pricing, education and information.

Furthermore, the rebound could be eliminated entirely by shaping the market for energy services so that it delivers to consumers packages of energy efficiency and renewable energy in which the economic savings from energy efficiency pay for all or part of the additional costs of renewable energy. Then there would be large reductions in CO_2 emissions, but no additional savings to spend on rebounds. Indeed, it is even possible to envisage scenarios in which people could be encouraged to invest money saved from an energy efficiency improvement in a further energy efficiency improvement.

Thus the rebound effect is a contingent phenomenon that can be eliminated entirely or even reversed with appropriate government policies.

5.5 Limitations of macroeconomic models

Macroeconomic models attempt to describe inherently non-linear phenomena by means of systems of linear equations (Blatt, 1983). In these equations, essentially all the coefficients are adjustable parameters. Most macroeconomic models of the costs of greenhouse response have additional unrealistic assumptions (Grubb et al., 1993; Diesendorf, 1998), for example:

[5] Unfortunately, plasma TVs and cheap Chinese air conditioners are exceptions.

- They assume, contrary to observation, that no cost-effective improvements can be made in the efficiency of energy use, based on existing technologies. This is sometimes expressed by the claim that people don't find $50 bills in the street. This incorrect result rises from the notion that there is a perfectly competitive market, which automatically implements all cost-effective energy saving technologies and measures as soon as they become are available. This ignores fundamental market failures, such as lack of knowledge, split incentives (for example, between landlord and tenant), inappropriate institutions, reversible behavioural patterns, transaction costs that can be removed be institutional change[6] and prices that do not reflect real costs (for example, because of subsidies to fossil fuels). Most general equilibrium models suffer from this defect, although a few attempt, with varying degrees of success, to marry bottom-up (engineering) models with top-down (macroeconomic) models.

- Instead of specifying the technologies for efficient energy use, they introduce meaningless parameters – for example, the 'autonomous end-use energy-intensity improvement' – and use other parameters such as 'elasticities' whose empirical basis is questionable.

- They assume 'constant returns to scale', a consequence of using a linear model to describe a non-linear phenomenon. This assumption fails to take account of the substantial observed reductions in costs of new technologies such as energy efficient appliances, solar hot water, and wind power as the scale of production and of the technology increases.

- They calculate costs, but rarely benefits, of greenhouse mitigation. This creates the false impression that any strategy for reducing emissions is going to be more expensive than doing nothing. Stern (2006) and presumably the Garnaut review will attempt to remedy this bias.

So, macroeconomic models of national economies are much less realistic than climate models, which are based on physical, chemical and biological mechanisms (Diesendorf, 2007a, Chapter 2). Yet some politicians and some economists perversely have high confidence in the former and doubts about the latter. Energy efficiency, in particular, receives a very unrealistic treatment by most macroeconomic models, with the result that it is greatly undervalued.

5.6 Employment

It is shown in Section 4.5 that there are more jobs created *in Australia* per unit of electricity generated from renewable electricity than from coal power. Furthermore, it is readily shown that the job losses in the Australian coal industry from a 25 per cent renewable energy target for 2020 could be addressed by not replacing a small fraction of the workers who retire annually from the coal industry.

According to data from the Australian Bureau of Statistics, the coal industry currently employs directly about 24,000 people in Australia. Taking account of the fact that 80 per cent of Australia's coal is exported, there are only about 4,800 workers employed in coal mining

[6] A new institution, energy service companies can reduce substantially the transaction costs of energy efficiency (Diesendorf, 2007a, pp.90–91).

for coal use in Australia. If renewable energy is increased from its current level of 9 per cent to 25 per cent of Australia's electricity by 2020 and if it all substitutes for coal power, this means that 16 per cent of 4,800 direct coal jobs or 768 jobs would be affected. Over the 12 years from 2008 to 2020, this is 64 coal jobs per year. Assuming that the average coal miner is employed for either 30 or 40 years (which is conservative in each case), this means that the average number of annual retirements is 24,000/30 = 800 in the first case and 24,000/40 = 600 in the second case. Thus the annual job losses are less than one-ninth of the expected annual retirements from the coal industry.

Even allowing for a generous multiplier factor of four for indirect coal employment would not change the qualitative result that job losses in the coal industry are easily accommodated by retirements and that many more jobs will be created in renewable energy.

6. Conclusion

(As in Executive Summary, page 6.)

Appendix A: Benefits of Removing Off-Peak Electric Hot Water

Coal-fired power stations are Australia's biggest single source of greenhouse gas emissions. At present cheap off-peak electric hot water tariffs keep a significant fraction of these power stations burning at full blast through the night, when demand for electricity would otherwise be much lower. This appendix shows that removal of off-peak tariffs and the phase-out of all-electric resistance heating of water could result in the retirement or deferral of several coal-fired power stations and a significant reduction in Australia's CO_2 emissions.

The calculation is performed initially for NSW, where approximately half the dwellings (1.15 million) have off-peak electric hot water. Apart from NSW, other States where the removal of off-peak electric hot water would achieve significant substitution of coal power are Queensland and South Australia. The national benefits of removing off-peak electric hot water would be approximately double those achievable in NSW.

Off-peak electric water heating generally takes place between midnight and 6.00 am. During that period, each household on an off-peak tariff heats water with a power of about 4 kW for about 3 (estimated) out of the 6 hours on each night. Therefore, on average over a year, a single electric resistance hot water system uses electricity amounting to
4 kW x (3 x 365) h = 4.4 MWh
and (assuming black coal) is responsible for the emission of about 4.4 tonnes of CO_2 per year.

According to ABS data, 1.15 million dwellings in NSW have off-peak electric hot water. Therefore, total annual electricity use for this purpose in NSW
= 4.4 MWh x 1.15 M
= 5,000 GWh
= 5 TWh.
This corresponds to the average annual electricity generation by a 750 MW coal-fired power station with capacity factor 75%. However, it is shown below that a much larger coal power capacity than 750 MW can be retired or deferred.

Since the generation of 1 TWh of black coal-fired electricity emits typically about 1 Mt of CO_2, annual NSW emissions from off-peak electric hot water heating are 5 Mt. Therefore, national annual emissions from these systems are about 10 Mt CO_2.

By phasing out off-peak electric HWS and replacing them with:

- solar-gas (where both solar access and gas are available); or
- gas (where gas is available but no solar access); or
- solar-electric (where solar but no gas is available); or
- electric heat pump (where neither gas nor solar access is available);

roughly 4 Mt of annual CO_2 emissions could be avoided in NSW and 8 Mt nationally. (This result allows for the emissions from boosting the solar systems, from gas hot water and from electric heat pump hot water.)

The amount of base-load generating capacity that could be retired or deferred depends on how many electrically boosted solar hot water systems and electric heat pump hot water systems are installed and whether they are allowed to heat during the night. Assuming, in the extreme case, that there will be no longer any electric water heating during the midnight-to-dawn period, the generating capacity of coal power to be retired in NSW would be:

4 kW x 0.5 x 1.15M = 2.3 GW.

The diversity factor = 0.5 allows for the likelihood that only about half the off-peak electric hot water systems are operating at any given time between midnight and dawn[7].

The electricity generation of this retired coal plant between 6.00 am and midnight could be substituted with approximately the same capacity of intermediate-load combined-cycle gas-fired power plant. The additional annual CO_2 emissions from this gas power plant in NSW, operating for 18 hours per day, would be about
0.4 Mt/TWh x (18/24) x 5 TWh = 1.5 Mt.

Thus the net annual saving of greenhouse gas emissions, from retiring the coal plant, retiring all electric hot water systems and increasing the gas plant in NSW, would become (5 – 1.5) Mt = 3.5 Mt, or 7 Mt for the whole of Australia.

[7] This author does not have any empirical data on this 'diversity factor' for hot water, so this is a rough estimate based on direct observation of a few systems.

Appendix B: Calculation of land areas required to supply Australia's electricity by wind and solar energy

B.1 Wind power area

Wind farms are highly compatible with agricultural and pastoral land use. While they span approximately 25 hectares per megawatt (ha/MW) of installed capacity, only about 1–2% of that land (0.25–0.5 ha/MW) is actually taken up by their towers, access roads and other equipment, while 98–99% of the land can continue to be used for crops or grazing.

For comparison, a fossil-fuelled 1000 MW power station has an average power output of about 850 MW or 7.5 TWh per year[8]. To substitute for this, about 2600–3000 MW of wind power capacity (depending upon wind speeds of the chosen sites) would have to be installed, spanning 65,000–75,000 ha (650–750 km^2), but only occupying physically 650–1500 ha (6.5–15 km^2). This is less than the area of a typical open cut coal mine required to serve the coal-fired power station (greater than 50 km^2).

Australia's total electricity demand in 2004 was 213 TWh/year, where 1 TWh = 10^9 kilowatt-hours (kWh). To supply 42.6 TWh per year, which is 20% of Australia's 2004 electricity generation (a reasonable long-term target for wind power), would require an area of land actually occupied of about 37–85 square km. This relatively small area of land is the result of the collection area of wind turbines (i.e. the area swept out by the blades) being vertical rather than horizontal.

B.2 Solar power area

Since there are 8760 hours per year, Australia total electricity demand in 2004 corresponds to an annual average power demand of 213 TWh/8760 h = 0.024 TW = 24 GW, where 1 GW = 10^9 W.

Average solar power absorbed by Earth's surface = 235 W/m^2.
For simplicity, assume initially only rooftop PV solar systems without concentrators. In practice, a significant fraction of solar electricity will come from solar power stations, both photovoltaic (PV) and solar thermal electric, both with concentrators – see below.

Assume 20% conversion efficiency, corresponding to best PV modules on the market. For comparison, best research laboratory efficiencies of PVs are approaching 30%.

With 20% efficiency, average solar power collected = (235 x 0.2) W/m^2 = 47 W/m^2.
Therefore, area required = $\frac{24 \times 10^9 \text{ W}}{47 \text{ W/m}^2}$

$$= 0.51 \times 10^9 \text{ m}^2$$
$$= 510 \text{ km}^2$$
$$= 23 \text{ km} \times 23 \text{ km}.$$

[8] This is optimistic compared with actual performance in NSW.

In other words, a square of area only 23 km x 23 km could supply all of Australia's 2004 electricity demand by converting solar energy at 20% conversion efficiency without concentrators. With concentrators, a much smaller area would be required.

Will the capture of solar energy increase global warming, as some people claim? Since Australia's surface area is about 7.7 million km^2, the land area required for solar energy is less then one ten-thousandth (1 part in 10^4) of Australia's total land area[9]. Before installing solar collectors, on average only about one-tenth of the sunlight falling on this land area is reflected – 90% is absorbed[10]. Therefore, the reduction in the reflectivity of the 510 km^2 area resulting from the installation of solar collectors would have a warming impact of less than one part in 10^5 of solar input and so a negligible impact on global warming.

Assume that Australia (population 21 million) has about 5 million houses, not counting apartments. Therefore, average area required per house to supply of Australia's 2004 electricity = 510/5 m^2 = 102 m^2.

This is a large area of roof. So, more realistically, let's consider that electricity is allocated to residential, commercial and industrial sectors according to demand. Since 28% of electricity is used by the residential sector (ABARE data), we assume that 28% of electricity is generated from rooftop PV modules and the remaining 72% by solar power stations with concentrators for industrial and commercial use. Then the average roof area per house required for residential electricity use = 28 m^2 which is easily achieved, even allowing for an additional 5 m^2 for solar hot water. Additional rooftop area is available from commercial and industrial buildings.

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[9] Strictly speaking, we should also allocate to Australia's land area about 10% of global ocean area as well.
[10] Most reflection of sunlight occurs above ground level (especiallyfrom clouds) and from snow and ice.

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