Paths to a Low-Carbon Future

Reducing Australia's Greenhouse Gas Emissions by 30 per cent by 2020

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Executive Summary

We have to think of tackling climate change as if we were treating cancer, the longer we leave it the harder it gets.[1]

Helen Liddell, British High Commissioner to Australia

Abstract

Interim targets to reduce greenhouse gas emissions are essential to put Australia on track toward the deep emissions cuts required by 2050. This report finds that by 2020, emission reductions of greater than 30 per cent below 1990 levels are possible, but only with a wide range of concerted actions in the energy, industry and land-use sectors. If the contributions from energy efficiency in the residential, commercial and industrial sectors are combined into a single category, energy efficiency emerges as the major source of greenhouse gas reduction to 2020. Renewable electricity with gas cogeneration could provide the largest potential "wedge" of supply-side reduction. Other large potential emission savings could be obtained from halting land clearing and cutting fugitive emissions from fossil fuel production and distribution. Urgent policy development and implementation, by both federal and state governments, is needed to facilitate these and other technologies and measures.

1. Interim greenhouse gas targets are vital

To prevent runaway global warming, which would become very likely if global average temperatures exceed 2°C above pre-industrial levels, the world community must cut greenhouse gas (GHG) emissions by at least 60 per cent by 2050. In line with their responsibility for a greater share of historic emissions, developed countries would have to make reductions of at least 80 per cent in this time frame. To get on track to this target, interim targets are vital. These are particularly important in the light of evidence being published, which shows that global warming is accelerating under the action of several amplification processes. A number of climate scientists and policy analysts are advising that developed nations must make GHG emission cuts of at least 30 per cent relative to 1990 levels by 2020, in order to make timely progress toward the long-term global target (Den Elzen, 2005). However, no Australian government, state or federal, has set interim reduction targets for dates earlier than 2050.

The dearth of interim targets may be explained by both major Australian political parties' hope that domestic emissions may in future be addressed by unproven technology which aims to capture, transport and bury greenhouse pollution from coal-fired power stations (carbon capture and storage, or CCS). Yet an interdisciplinary panel of experts found that almost two decades will pass before global pick up of CCS is possible, should the technology prove to be feasible (Ansolabehere et al., 2007).

2. Business-as-usual demand growth is not sustainable

The baseline or reference case for this study is the business-as-usual (BAU) "with measures" scenario published by the Australian Greenhouse Office (AGO). This scenario envisages annual emissions growth from 565 Mt of carbon dioxide equivalent (CO_2-e) in 2004, to 702 Mt in 2020, a total growth of 24 per cent. Such a rapid growth, if it actually comes to pass, poses an enormous challenge to an emissions reduction program. If such rapid growth is allowed to eventuate and continue beyond 2020, it would completely swamp any technological reduction measures that could be implemented over the next quarter-century. Nevertheless, we have used this AGO scenario as a baseline to 2020, while recognising that growth in energy demand and its associated emissions must be halted.

1 AAP Australian General News Wed 18 Apr 2007 6:52 pm.

3. Thirty per cent reductions are possible by 2020

This report developed two emission reduction scenarios, which are outlined separately below.

3.1 Scenario 1

Scenario 1 is limited to technological changes in the energy sector. While not spanning all possible measures, it implements mainly:

- efficient energy use and solar heat in the residential, commercial and industrial sectors;
- the lowest cost renewable electricity sources (wind and some forms of bioelectricity), together with an increase in generation and cogeneration with natural gas;
- modest improvements in public transport and a significant shift from petrol/diesel motor vehicles to hybrid, plug-in hybrid and all-electric vehicles; and
- a big percentage reduction in fugitive emissions from fossil fuels.

The results are that implementing Scenario 1 measures would result in a CO_2-e emissions reduction of 222 Mt per annum, from the 2020 BAU baseline of 702 Mt, to 480 Mt, which is 13 per cent below the 1990 level.

Although Scenario 1 did not achieve the chosen target of a 30 per cent reduction below the 1990 level, the result is encouraging. It shows that energy efficiency, solar hot water, renewable electricity and gas cogeneration, and improved transportation are able to reverse BAU growth in emissions by 2020. However, beyond 2020 we must expect to run up against the limits to energy efficiency, deployment of solar hot water and natural gas reserves. Therefore, the underlying drivers of growth in demand must also be addressed.

3.2 Scenario 2

Some of the drivers of demand growth are addressed in Scenario 2, which includes all the measures of Scenario 1 plus several non-energy measures, such as reductions in emissions from land use (including agriculture), population growth, and a very energy-intensive industry, aluminium smelting. Scenario 2 succeeds in reducing Australia's emissions in 2020 to 372 Mt per annum, a reduction of 33 per cent below the 1990 level. Thus our target is exceeded, but not without including some potentially controversial measures.

Controversial or not, all the measures used in Scenario 2 are safe, effective, available now and require no major technological breakthroughs. Thus this study confirms that there is no need to rely upon unproven, risky technologies with long development times, such as coal power with CCS. Nor would we need nuclear power stations, the fuelling of which would inevitably cause significant emissions of CO_2 as limited reserves of high-grade uranium ore are used up (Diesendorf, 2007a and b).

The largest wedge of reductions in Scenario 2 was obtained through renewable electricity with cogeneration (54 Mt per annum in 2020). (To put this emissions saving into perspective, a typical 1,000 MW black-coal power station built in the 1990s emits 5-6 Mt of CO_2-e per annum.) This wedge includes quite large contributions from wind power and bioelectricity.

Other large wedges are 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). However, if we had combined into a single wedge the energy efficiency and solar hot water measures from the residential, commercial and industrial sectors, it would be by far the biggest contributor (80 Mt).

Achieving the 2020 target also included small contributions from several promising clean technologies and measures. These include solar thermal electricity, solar photovoltaic electricity, hot rock geothermal power[2],

2 Although hot rock geothermal power has not yet been demonstrated, it is included because it requires no major technical breakthroughs and is a safe and clean technology.

plug-in hybrid and all-electric vehicles, and further upgrades to urban public transport. Although only capable of minor contributions by 2020, each of these technologies has the capacity to produce substantial additional reductions beyond 2020.

Although this study did not perform an economic analysis, we note 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.

4. Implications for policy

The previous section illustrates the importance of strong government and business support for efficient energy use and renewable energy. In general, none of the wedges contributing to this target can be achieved without new policies by federal and state governments. Clearly, the current policy neglect of energy efficiency, wind power, bioenergy, cogeneration, solar electricity, public transport and electric vehicles must be reversed. With strong support for industry development, market development and technological development, these clean energy technologies could possibly make even greater contributions by 2020, perhaps negating the need for some of the more politically challenging non-energy measures cited in this report.

The necessary policies must involve setting emission reduction targets[3], carbon pricing, mandatory renewable energy targets (MRETs), regulations and standards for energy efficiency, institutional changes, education and R&D funding (Diesendorf, 2007a). Funding for the transition can be obtained from carbon pricing, MRETs, the application of mass-distance charges to road freight, and the removal of existing government subsidies to the production and use of fossil fuels (Riedy and Diesendorf, 2003; Riedy, 2007).

3 In megatonnes, not in terms of percentage reductions in growth from a projected future BAU level.

1. Introduction

To prevent global average temperatures from rising above 2°C over pre-industrial levels, the world community must reduce greenhouse gas (GHG) emissions by 60 per cent by 2050. In line with their responsibility for a greater share of historic emissions, developed countries must make 80–90 per cent cuts in this time frame. To get on track to this target, interim targets are also vital. To make timely progress toward this global long-term target, several estimates suggest that developed nations such as Australia must make greenhouse pollution cuts of at least 30 per cent relative to 1990 levels by 2020 (Den Elzen, 2005).

This report, prepared by the author following discussion and some support from Greenpeace Australia Pacific, aims to explore pathways to this 30 per cent target using GHG abatement measures represented as a series of "wedges". This term refers to activities or measures which have GHG emissions increasing or decreasing linearly over their deployment timeframe. Thus, on a graph of emissions over time, each measure forms a characteristic wedge shape, as shown in Figures 1 and 2.

There can be no doubt that achieving this 30 per cent reduction is an ambitious task. The reasons for this are multiple. One is that past inaction has left Australia's *energy-related*[4] emissions largely unaddressed; these emissions are expected by government agencies to almost double over the period from 1990 to 2020. Yet Australia's *total* emissions are projected to increase by a more modest 27 per cent of 1990 levels by 2020. This deceptively low increase in total emissions reflects a special one-off concession demanded by, and conceded to, Australia during Kyoto Protocol negotiations; it allows Australia to claim credit for emissions avoided by land clearing reductions[5].

The high rate of energy-related emissions growth, which will be unmasked as land clearing is phased out, is projected to continue unabated under "business as usual" (BAU) scenarios. These soaring growth rate forecasts hold true whether they are based on past growth, on projections by the Australian Bureau of Agricultural and Resource Economics (ABARE), or on projections by the Australian Greenhouse Office (AGO).

It will be a challenge to reduce emissions to 30 per cent below 1990 levels. Yet this huge but inevitable shift in our energy use will only become more costly and difficult with each year of delay. The author finds that to achieve 30 per cent cuts we must address some drivers of emissions growth, as well as make the necessary technological shifts. These drivers are the growth in greenhouse-intensive industries and lifestyles, population growth and technology choice.

Some measures included in this analysis, such as solar electricity and enhanced urban public transport, will only be capable of making relatively small contributions by 2020. These measures are included because of their importance to any long-term emissions reduction plan.

It must be cautioned that the limited availability of reliable data imposes constraints on this and other analyses. For example, the breakdown of BAU emissions projections by ABARE and AGO is not sufficiently detailed to permit the author to examine differing growth rates of the various energy services. Key data on industrial heat use (for example, temperature distribution) is unavailable. Furthermore, 1999 is the last available year for data on end-use for Australia's GHG emissions (Wilkenfeld, 2002); an update would be valuable to all with an interest in this crucial policy area. These data limitations make inevitable a degree of uncertainty and arbitrariness in projections to 2020 of emissions from various energy services.

A further challenge in this analysis is to select and tabulate wedges to avoid double counting of emissions reductions. This demands careful scrutiny of measures, since a single policy action may have multiple consequences.

To address the above constraints, the author spells out assumptions made for each wedge. However, these constraints impose an important caveat on each wedge: that it is an approximation of the emissions reductions assigned to it, given the available data.

4 Refers to emissions from stationary energy, transport, and fugitive sources.

5 Loss of vegetation through land clearing and deforestation results in GHG emissions, as the carbon stored in plants, trees and soils is released into the atmosphere.

2. Method

This section discusses the measures and some key assumptions used to answer the question: how can Australia achieve 30 per cent GHG emissions reductions by 2020, over 1990 levels? The study starts with information on recent trends in Australia's GHG emissions and business-as-usual (BAU) projections of future emissions by government agencies. This section also clarifies the target and the data sources used.

2.1 Recent emissions trends

Table 1 lays out recent data on Australia's GHG emissions trends. Total growth in annual GHG emissions has been relatively small at 2.4 per cent, from 552 megatonnes (Mt) of carbon dioxide equivalents[6] (CO_2-e) in 1990 to 565 Mt in 2004. However, as discussed in the introduction, this total reflects a large reduction in emissions resulting from reduced land clearing, which offsets major recent growth in energy-related emissions. As Table 1 shows, the "Land use and forestry" emissions reduction of 72 per cent helped compensate, for example, for very considerable emissions growth of 34.4 per cent in energy use during the period 1990–2004.

2.2 BAU growth projections for 2020

According to the AGO's BAU "with measures" scenario, total annual GHG emissions are expected to reach 702 Mt CO_2-e by 2020, an *increase* of 27 per cent over 1990 levels, or 24 per cent over 2004 levels. AGO's term "with measures" refers to continuation of existing federal greenhouse abatement measures of marginal or questionable benefit, such as the Greenhouse Challenge (a voluntary program) and Generator Emissions Standards.

Under the BAU scenario, annual land clearing and forestry emissions are projected to fall 33 per cent from 2004 levels, but are still not completely eliminated by 2020. Without this land clearing offset, emissions growth would be higher. For example, stationary energy and transport emissions are projected to grow, respectively, by 29 and 30 per cent during this period, an average annual growth rate of about 1.7 per cent.

Once land clearing is completely eliminated, Australia's total emissions growth will be exposed to the full pressure of growth from energy use and other sectors. However, any responsible greenhouse scenario entails putting an end to land clearing well before 2020, because stopping land clearing is among the least-cost ways to reduce emissions and also has considerable biodiversity benefits.

6 As well as CO_2, this includes other greenhouse gases, such as methane (CH_4) and nitrous oxide (N_2O), which are converted to CO_2 equivalents (CO_2-e) in terms of their global warming potential.

Table: 1: Australia's past and projected greenhouse gas emissions ($Mt\ CO_2$-e), Kyoto accounting

Source of columns 2–4: Australian Greenhouse Office (2006a); columns 5 & 6: Australian Greenhouse Office (2006b)

	1990 emissions (Mt)	2004 emissions (Mt)	Per cent growth 1990–2004	AGO 2020 BAU "with measures" (Mt)	AGO per cent growth 2004–20
Total	**552**[b]	**565**[b]	**2.4%**[a]	**702**	**24%**
Energy	288	387	34.4%	516	33%
Stationary energy	196	280	43%	361	29%
Electricity	129	195	51%	241	23.5%
Heat	66	85	29%	120	41%
Transport	62	76	23%	99.5	30%
Cars	35.2	41.7	18%	49.0	18%
Vans	7.6	10.8	45%	18.3	69%
Heavy trucks	10.2	15.1	35%	18.6	23%
Aviation	2.9	4.8	66%	7.0	46%
Fugitive	30	31	3%	55.4	79%
Industrial process[c]	25	30	20%	50	67%
Agriculture	91	93	2%	101	8.6%
Land use & forestry	129	36	-72%	24	-33%
Land use change	129	53.3	-59%	45	-16%
Forestry	0	-17.8	-18%	-21	-3.7%
Waste	19	19	0%	11	-42%

Notes:

a As discussed above, small total emissions growth (2.4 per cent) from 1990-2004 is due to the decline in land clearing emissions, which largely compensated for the huge (34.4 per cent) energy emissions growth.

b The proposed target in this report for Australia's total CO_2-e emissions in 2020, 386 Mt, is 32 per cent below the 2004 level and 30 per cent below the 1990 level.

c "Industrial process" refers to GHG emissions not from energy generation and use, for example, emissions released during chemical processes for cement production.

2.3 Clarifying the 30 per cent target

The reference case used for the study is the AGO's BAU "with measures" scenario. Given that this scenario projects annual GHG emissions to *increase* to 702 Mt by 2020 (27 per cent above 1990 levels), a 30 per cent *reduction* over 1990 levels requires that the measures of this study reduce annual GHG emissions by at least 316 Mt, to 386 Mt at 2020.

2.4 Other key data and issues

Electricity greenhouse intensity: In addition to the above Table 1 data on BAU emissions, the author's calculations used Australia's electricity generation figure of 213 TWh (terawatt-hours) for 2003-04. Thus, the average greenhouse intensity of 2004 electricity generation was 195 Mt/213 TWh = 0.915 Mt CO_2-e/TWh or 0.915 t CO_2-e/MWh (megawatt-hour).

To provide a real-world comparison for the various emission reduction measures cited in this report, the approximate annual CO_2 emissions of selected base-load power stations are given in Table 2. For fossil fuel power stations, CO_2 emissions are a very good approximation to CO_2-e emissions (i.e. their total GHG emissions).

Table 2: Annual CO_2 emissions from several base-load power stations

Power station & state	Type of coal	Capacity (MW)	Annual emissions (Mt)
Hazelwood, Vic	Brown	1,600	17.3
Loy Yang A, Vic	Brown	2,000	17.3
Bayswater, NSW	Black	2,640	14
Yallourn, Vic	Brown	1,480	13.4
Loy Yang B, Vic	Brown	1,000	9.7
Mt Piper, NSW	Black	1,320	7.6
Wallerawang C, NSW	Black	1,000	4.7

Source: Compiled by the author from a variety of sources, including annual and environmental reports of generators.
Note: Brown coal stations have much higher greenhouse intensities (emissions/kWh) than black coal stations.

End-use analysis: To assess the effect of policies and measures on society's GHG emissions, we must first determine the baseline emissions from various "energy services". An energy service is a task or service that involves energy as an input: for example, home heating, office illumination, refrigeration, hot showers and transportation. Here the focus is on the service, rather than the quantity and type of energy supplied. The challenge for the author is that the National Greenhouse Gas Inventory (NGGI) does not classify and break emissions down into energy services.

To estimate emissions from such energy services, the author makes use of an analysis conducted on the NGGI's 1999 and 1990 figures (Wilkenfeld, 2002) which sets out emissions for particular end uses. For example, Wilkenfeld's study of residential sector emissions finds the proportions of emissions listed in Table 3.

Table 3: Percentage of residential GHG emissions by energy service category, 1999

Residential end use	Percentage of total residential emissions
Lighting	8
Hot water[7]	27
Space heating and cooling	18
Appliances	42

Source: Wilkenfeld (2002)
Note: Total 1999 residential emissions were 22 per cent of total national stationary CO_2 emissions.

Wilkenfeld's analysis is most useful for the residential sector. (Note that, since Wilkenfeld uses IPCC inventory accounting, not the Kyoto Protocol accounting of NGGI, his values for emissions differ somewhat from those of the NGGI.)

Efficient energy use: Energy efficiency comprises a myriad of technologies and measures. As users of Australia's very low cost (but polluting) energy, domestic energy consumers have little economic incentive to increase energy efficiency. The National Framework for Energy Efficiency[8] studies and other research, such as the report *A Clean Energy Future for Australia* (Saddler, Diesendorf & Denniss, 2004), reveal the large potential for cost-effective energy efficiency measures. It has also been shown that such energy efficiency investments would enjoy much shorter payback periods than would equivalent investments in power stations.

However, calculations of energy efficiency gains are challenging due to the above-mentioned lack of data on current and projected GHG emissions for the various energy services. The author cautions that this constraint requires the formulation of crude assumptions about the BAU energy service growth rates for industrial and commercial sectors.

7 This is a national average; the proportion of hot water emissions is higher in NSW and QLD due to a higher share of electric hot water systems, and lower in Victoria and WA where gas hot water heating is prevalent.
8 <www.nfee.gov.au>

2.5 Description of emission reduction measures

The Coalition Government's central proposals to tackle climate change hinge on technology called carbon dioxide capture and storage (CCS), and on nuclear power. CCS is an unproven technology, and the Coalition Government's nuclear proposal likewise entails a generation of nuclear reactors that have not yet been built. Realistic appraisals find that neither of these technologies is likely to make a significant contribution before 2020, if ever (Saddler, Riedy & Passey, 2004; Diesendorf, 2007a; Ansolabehere, 2007). For this reason, and because they entail significant social, health, environmental and economic risks and unknowns, these technologies are excluded from this report.

Nuclear power in particular is rejected because of its substantial risks (proliferation of nuclear weapons, terrorism, waste management and reactor failures) and economic costs, and because within several decades it will become a significant emitter of CO_2, mainly from the fossil fuels used in mining and milling low-grade uranium ore. Based on existing technologies, nuclear power is neither a long-term nor a short-term solution to global warming (Diesendorf, 2007a and b).

Evidence that global climate change is accelerating (Pittock, 2005; IPCC, 2007), with positive feedbacks from melting ice, snow and permafrost and possibly from warming soil, illustrates the urgent need for substantial emission reductions over the next decade. Thus this report concentrates on safe and practical measures, most of which are available now, or can reasonably be expected to become available over the period studied, as they require no significant technological breakthroughs. Some of the measures included, such as enhanced urban public transport, changes in urban design, and shifting to large-scale biofuel use, will only be capable of making small contributions by 2020. These measures are nonetheless included in this analysis, because they entail none of the above risks, are proven technologies, and are of key importance to any long-term emissions reduction plan beyond 2020.

3. Two scenarios for reducing emissions

This study examines two scenarios for reducing Australia's greenhouse gas emissions by 2020. Scenario 1 is restricted to the energy sector, addressing basic measures in efficient energy use, solar hot water, renewable energy, transport and fugitive emissions. Scenario 2 starts with all the measures of Scenario 1 and then adds some measures related to changes in lifestyle, industry policy, agriculture and land use, and population policy. Both scenarios apply emission reduction measures to the projections from the AGO's "with measures" scenario (annual emissions of 702 Mt CO_2-e by 2020).

3.1 Scenario 1 measures

The results for Scenario 1 can be found in Table 4. These measures are described in greater detail below. Measures 3.1.1 – 3.1.4 are demand-side measures, in the sense that they propose to reduce the use of fossil fuels through energy efficiency and solar heat. They are followed by supply side measures (3.1.5 – 3.1.6) and measures to reduce fugitive emissions from fossil fuels (3.1.7).

3.1.1 Residential sector, demand-side

Wilkenfeld (2002) found that baseline annual residential stationary energy emissions were 63 Mt in 1999. He also found that the growth rate over the period 1990–1999 was 1.9 per cent per annum. If we extrapolated this to 2020, we would obtain a total BAU growth of 32 per cent over 1999–2020, yielding 83 Mt in 2020. This would be an over-estimate since there is a limited number of appliances of a given type that households will purchase. Therefore, taking into account this saturation effect, we estimate an overall 22 per cent BAU growth in residential emissions over the period 1999-2020, to 77 Mt per annum.

Residential hot water: Heating for hot water produces 27 per cent of residential energy-related stationary emissions. Thus we estimate BAU residential hot water emissions to be 21 Mt per annum by 2020, based on the above 77 Mt total residential emissions figure. Emission reduction measures would include:

- Installing water-efficient shower-heads and aerators.
- Ensuring 100 per cent of houses are equipped with solar, gas or heat-pump hot water supply (we assume 100 per cent per cent turnover is achievable within 14 years).
- Making gas-boosted solar mandatory wherever both gas and solar are available. Where solar is available without gas, electrically-boosted solar hot water becomes mandatory. Where there is insufficient solar access, gas or heat-pump hot water becomes mandatory.

Necessary policies include the removal of off-peak electric hot water rates, the banning of new all-electric hot water systems other than heat pump systems, and incentives for the installation of solar hot water. Emission reduction: 16.6 Mt.

Residential space heating and cooling: Annual emissions from this end-use accounted for 11.3 Mt of emissions in 1999, and the author estimates they will increase to 14 Mt by 2020 under BAU. The proposed emission reduction measures are strict mandatory energy performance standards for new homes, plus incentives for solar space heating for half of all homes, both new and old. Emission reduction: 7.7 Mt.

Residential lighting: Lighting is responsible for 8 per cent of residential stationary emissions. This end-use accounted for 5.1 Mt of GHG emissions per annum in 1991, and we estimate it will reach 6.2 Mt in 2020 under BAU. It is technically and economically feasible to improve residential lighting efficiency by 75 per cent by phasing out incandescent bulbs, a measure which has recently been adopted as Federal Government policy. Emission reduction: 4.6 Mt.

Residential appliances: Forty two per cent of residential emissions arise from the use of appliances. This end-use accounted for emissions of 29 Mt per annum in 1990, expected to increase by 22 per cent to 35.5 Mt by 2020 under BAU. The emissions reduction measure proposed for this end-use entails a 20 per cent improvement in appliance efficiency, yielding an emissions reduction of 7.1 Mt.

3.1.2 Commercial sector, demand-side

In 1999, commercial sector GHG emissions were 46.6 Mt per annum. Wilkenfeld (2002) finds an annual growth rate in these emissions of 3.8 per cent over 1990–1999. If this growth rate still held to 2020, emissions from this sector would grow by 119 per cent to 102 Mt. Again allowing for saturation effects, this analysis estimates these emissions will grow to 70 Mt at 2020 under BAU. Stationary energy use (from using electricity, as well as from directly burning petroleum, gas and coal) is responsible for the vast majority of commercial sector emissions (Wilkenfeld, 2002). More than half of total commercial sector emissions result from heating, ventilation and air conditioning (HVAC), and about one-quarter from lighting. We assume these proportions hold to 2020.

Commercial energy efficiency: The measures in this report entail a reduction in lighting emissions of 40 per cent through efficiency improvements (7 Mt), and a reduction in HVAC emissions of 20 per cent, also through efficiency improvements (7 Mt).

3.1.3 Industrial sector, demand-side

Australia's industrial emissions were 116 Mt per annum from stationary energy use in 1999 (Wilkenfeld, 2002). Aluminium smelting accounted for 52.5 Mt of these emissions (including non-energy emissions[9]), and remaining industry (i.e. other metal production, cement production, chemical industry) for 63.5 Mt. Excluding aluminium smelting emissions (which are dealt with separately in Scenario 2), we assume average BAU demand growth of 50 per cent for remaining industry from 1999–2020, to 95 Mt (see Appendix A for further explanation of this assumed growth rate).

Industrial process heating: Estimates of industrial process heating emissions at 2020 are a rough approximation. They are based on 1999 end-use emissions of 36 Mt per annum (Wilkenfeld, 2002; p. 117, figure 8.1) and are projected to be 54 Mt at 2020. This measure proposes to replace low-temperature heating (currently mostly gas-powered) with solar thermal. We assume 20 per cent of this heat could be supplied by solar thermal, thus saving 11 Mt. We assume emissions saved for this measure are separate from those saved by obtaining heat through cogeneration (see "Renewable electricity with cogeneration" measure below) and energy efficiency (directly below).

Industrial energy efficiency: As noted above, industrial sector emissions, excluding those from aluminium smelting, are projected to grow from 63.5 to 95 Mt per annum for the period 1999–2020. This refers to emissions from stationary energy use. We propose that energy efficiency measures will reduce the average BAU industrial energy use in 2020 by 20 per cent, giving a reduction of 19 Mt. This measure is in addition to cogeneration (see "Renewable electricity with cogeneration" measure below) and "Industrial process heating" (described above).

Industrial process (non-energy): This measure refers to industry GHG emissions that are not directly related to energy consumption. This author rejects AGO's assumed huge acceleration of the BAU growth rates for these emissions, to a rate of 67 per cent from 2004-2020, growth that would result in projected emissions of 50 Mt per annum by 2020. Instead the author proposes in this measure that this sub-sector's growth rate is constrained to 1990-2004 levels, which is 20 per cent, yielding 36 Mt in 2020. This is therefore a reduction of 14 Mt compared with AGO's BAU projection.

3.1.4 Transport sector, demand-side

In 2004, passenger vehicles (almost entirely cars) were responsible for 41.7 Mt of emissions per annum, an increase of 18 per cent above the 1990 level, while trucks were responsible for 15.1 Mt, an increase of 35 per cent above the 1990 level. We assume that under BAU these growth rates would continue to 2020, when emissions would become 49.2 Mt and 20.4 Mt, respectively.

9 Since 1999, the industry has reduced substantially the non-energy emissions from aluminium smelting (e.g. perfluorocarbons [PFCs]).

Passenger transport: This measure proposes to reduce passenger transport emissions from 2020 BAU levels to the 2004 level by expanding urban public transport and expanding facilities to promote cycling and walking. Emissions reduction from BAU: 7.5 Mt.

Freight transport: This report assumes that higher pricing of diesel fuel and the recovery of road maintenance costs from heavy trucks will stop demand growth for long-distance road freight, holding these emissions steady at the 2004 level to 2020. Emissions reduction from BAU: 5.3 Mt.

3.1.5 Renewable electricity with cogeneration

This and the remaining Scenario 1 measures below are supply-side measures.

According to International Energy Agency data, 84 per cent of Australia's electricity came from fossil fuel sources in 2004 (IEA, 2006). "New" renewable sources such as wind and solar accounted for only about one per cent of total electricity generation, while conventional hydroelectric power made up the remainder. Coal power is Australia's largest single source of GHG emissions. Because renewable sources have zero or very low emissions, their role in reducing Australia's emissions is vital.

The total BAU greenhouse gas emissions from electricity in 2020 are assumed to be the AGO projection given in Table 1 of 241 Mt per annum. The additional emissions from an increased use of plug-in hybrid and all-electric motor vehicles are treated separately in Section 3.1.6 as part of the calculation of net emission reductions in transport supply.

The principal renewable energy supply technologies that have the potential to significantly reduce GHG emissions through to 2020 are wind power and bioelectricity. Increased use of natural gas and coal seam methane would also contribute to reducing the greenhouse intensity of electricity generation by 2020. Solar thermal electricity (with water, rock or thermochemical heat storage) and hot-rock geothermal power can be expected to make some contribution, however, not a substantial one before 2020. Based on these assumptions, this analysis proposes the following renewable energy and cleaner energy measures.

- **Wind** generation grows to 21.3 TWh per year by 2020, an installed capacity of approximately 8 GW. For comparison purposes, this would correspond to about 10 per cent of 2004 electricity generation. Wind power from geographically dispersed sites, with occasional back-up from peak-load gas turbines, can provide 24-hour power and is therefore base-load generation (Diesendorf 2007a and c).
- **Bioelectricity,** a base-load power source, grows to 17 TWh per year by 2020 with installed capacity of about 2.3 GW. This would correspond to approximately 8 per cent of 2004 electricity generation. We assume that most biomass for this measure comes from wheat stubble, plantation forest waste, sugar plantation waste, and oil mallee; hence no land is transferred from food production to bioenergy production. Indeed, oil mallee can help to combat dryland salinity and hence will make more land available to food production.
- **Solar thermal** electricity, another base-load power source, grows to 5.3 TWh per year by 2020, a level corresponding to about 2.5 per cent of 2004 electricity generation. Here we refer to solar thermal electricity with water, rock or thermochemical storage.
- **Solar photovoltaic (PV)** power grows to 5.3 TWh per year 2020, a level corresponding to about 2.5 per cent of 2004 per cent electricity generation. It is assumed that battery storage will still be expensive by 2020, and so solar PV contributes to intermediate- and peak-load electricity supply, but not to base-load.
- **Geothermal** power from hot fractured rock is a base-load power source that is still under development. However, it does not require any major technical breakthroughs and the first demonstration plants are expected to be operating within a few years. Thus we estimate it will contribute 1 GW of capacity with annual electricity generation of 7.5 TWh by 2020.

- **Hydroelectricity:** While there may be small increases in hydroelectric generating capacity from new small dams and improved efficiency of existing hydro power stations, it is assumed that these will be offset by reduced precipitation. Thus no increases in hydroelectric generation are proposed.

The total contribution of renewable energy in 2020 becomes 56.4 TWh, of which 51 TWh is base-load. The renewable energy contribution is equivalent to 26 per cent of 2004 electricity generation. Given that the 2004 greenhouse intensity of Australia's electricity supply was 0.915 Mt CO_2-e/TWh, these renewable sources of electricity[10] could save a total of 46.8 Mt CO_2-e per annum.

In addition, industrial and commercial gas-fired **cogeneration** could substitute for 5 per cent of 2004 coal-fired electricity generation (10.6 TWh) in 2020. In this study, we attribute the emissions from cogeneration to its electricity generation component. Therefore we assume that all heat produced in cogeneration is emissions-free and is used to substitute for gas heating.

3.1.6 Transport sector, supply-side

Biofuels for transportation: Some liquid fuels from biomass residues using first generation technologies (e.g. ethanol from starch and sugar; biodiesel from used cooking oil and tallow) are economically viable at 2007 oil prices. However, only limited quantities of biofuel can be produced from these low-cost residue sources. These could be useful for essential transportation services (for example, in the event of a sudden constraint on oil imports) and so merit further development.

The future of *large-scale* biofuel use depends on the development of low-cost, second-generation technologies, such as ethanol and methanol from lignocellulose (a structural component of woody plants). Second-generation biofuel technologies are not yet close to commercial availability, although rapid research advances suggest large contributions are possible beyond 2020. Therefore, this report will adhere to existing technologies and will not consider large-scale biofuel use before 2020. Rather, this report proposes the use of rechargeable hybrid and all-electric cars and vans as supply-side transport measures; these measures will achieve progressively greater emission reductions as Australia's electricity supply becomes "greener".

Plug-in hybrid cars[11]: In 2004, 41.7 Mt of annual GHG emissions came from passenger vehicles, almost entirely cars. For this report, we propose that 85 per cent of Australia's motor cars (100 per cent of urban-based vehicles) are plug-in hybrids by 2020. We assume this measure results in a 50 per cent average fuel reduction per vehicle. In our calculations of GHG reductions (Appendix A), we take account of the fact that reduced petrol consumption will be partially offset by emissions from production of electricity that the cars consume[12]. Thus we obtain a net emissions reduction of 12.8 Mt per annum.

Electric vans for all urban deliveries: In 2004, light commercial vehicles (LCVs) were responsible for 11 Mt of annual GHG emissions. We assume that under BAU this figure will grow by 2.7 per cent each year, to 16.8 Mt in 2020. For this measure, we propose that all LCVs become pure electric vehicles by 2020. Electric vehicles are much more efficient for deliveries (which involve frequent starting and stopping) than those with petrol/diesel engines. In our calculations of GHG reductions, we take account of the emissions generated by the LCVs' increased electricity use (see Appendix A). The net emissions reduction obtained is 4.5 Mt.

Freight trucks and buses: Emissions from trucks and buses were 15.1 Mt in 2004. As noted above, we assume that demand management and road pricing stop the increase in freight truck use to 2020. Looking to solutions, we note that a major switch to biodiesel is not feasible, because current low-cost sources of biodiesel (e.g. tallow and used fish and chips oil) are very limited in quantity and because vast areas of land would be required to grow sufficient oilseed crops for a major switch. Therefore, this measure entails the following mix of technologies:

10It has been assumed that that the greenhouse gas reductions from solar PV compensate for the additional use of gas turbines to back-up wind power.

11 Plug-in hybrids are hybrid vehicles with electric motors that can be recharged by plugging into a regular electrical outlet. They can attain fuel efficiencies of 2.3 l/100 km or greater. In July 2007 Toyota was granted government permission to run its test plug-in hybrid vehicle on Japanese public roads.

12 Based on 2020 emissions intensity for grid-based electricity of 0.695 Mt CO_2/TWh.

- 10 per cent of trucks fuelled by 100 per cent biodiesel, for a 90 per cent reduction in emissions for these vehicles;
- 30 per cent of trucks fuelled with diesohol E20 (20 per cent ethanol + 80 per cent diesel) for a 20 percent reduction in emissions for these vehicles;
- 30 per cent of trucks switch to hybrid diesel-electric, with 30 per cent reduction in emissions for these vehicles.

The emissions reduction obtained (see Appendix A) is 3.6 Mt.

3.1.7 Fugitive emissions

"Fugitive emissions" refers to GHG emissions released as a by-product of extracting, processing and transporting the fossil fuels. The AGO's BAU "with measures" scenario projects surprisingly high fugitive emissions growth of 79 per cent over the 2004–2020 period, versus the far more modest growth of 3 per cent witnessed from 1990-2004. To address this, we propose measures to ban flaring and venting of GHGs from new gas and oil fields. We also assume that CO_2, mixed with natural gas extracted from new gas fields in the North West Shelf, will be captured and geosequestered, as is currently planned for the Gorgon gas field. We also propose further measures that put strict, mandatory pollution limits on existing gas and oil fields, gas pipelines, and underground coal mines. In total, these measures could reduce these fugitive emissions by 75 per cent. The remaining emissions, from open-cut coal mines, appear to be intractable.

3.2 Scenario 2 measures

Scenario 2 employs the measures from Scenario 1 and the additional measures described below. The aim is to tackle underlying drivers of emissions growth that are projected under the AGO's BAU "with measures" scenario (24 per cent growth, from 565 to 702 Mt per annum for the period 2004-2020).

These additional measures were selected following close scrutiny of all three basic drivers of emissions growth: growth in population, affluence (as measured by GDP/person) and polluting technology. They were furthermore chosen to be equitable and compatible with Australian society's well-being. These measures are technically and economically viable, but some are potentially politically challenging. These issues are elaborated on further in the report's Discussion section.

3.2.1 Removing aluminium smelting emissions

The highly energy-intensive aluminium smelting industry consumed 13 per cent of Australia's electricity generation in 2004. It is heavily subsidised by other electricity consumers (Turton, 2002). In the appendix the author estimates the energy-related component of emissions from aluminium smelting to be responsible for about 28 Mt annually. This report proposes to completely eliminate or offset the energy-related emissions from aluminium smelting. This can be achieved by removing subsidies on electricity currently provided to aluminium smelters, and by requiring the industry to participate in carbon pricing.

3.2.2 Reducing agriculture emissions

In this measure we assume that continuing drought resulting from climate change limits agricultural emissions for the year 2020 to the 2004 level of 93 Mt per annum, rather than the 101 Mt of the AGO's BAU "with measures" projection. Furthermore, this report proposes to reduce beef consumption by 20 per cent, as this agricultural sector makes the biggest contribution to Australia's methane emissions. This could be accomplished by shifting to kangaroo meat and/or lower-meat diets.

3.2.3 Ending land clearing and deforestation

Land clearing was responsible for 53 Mt of annual GHG emissions in 2004, and the AGO's BAU "with measures" scenario assumes it will be 45 Mt in 2020. This report proposes a complete end to land clearing and deforestation by 2020, so that there are no net emissions from this source.

3.2.4 Reducing business and professional immigration

Australia's population is expected to grow from its 2001 level of 19.4 million to 23.3 million by 2020. This represents a population growth of 20 per cent over this period (2001–2020). The average growth rate for total emissions is higher, about 1.3 per cent per annum. Population growth is a significant driver of residential emissions growth, for both stationary energy and transport. Regardless of their country of origin, immigrants tend to adopt Australia's energy-intensive lifestyle on arrival. Since Australia has the highest per capita greenhouse gas emissions in the world, immigrants will on average tend to increase their emissions.

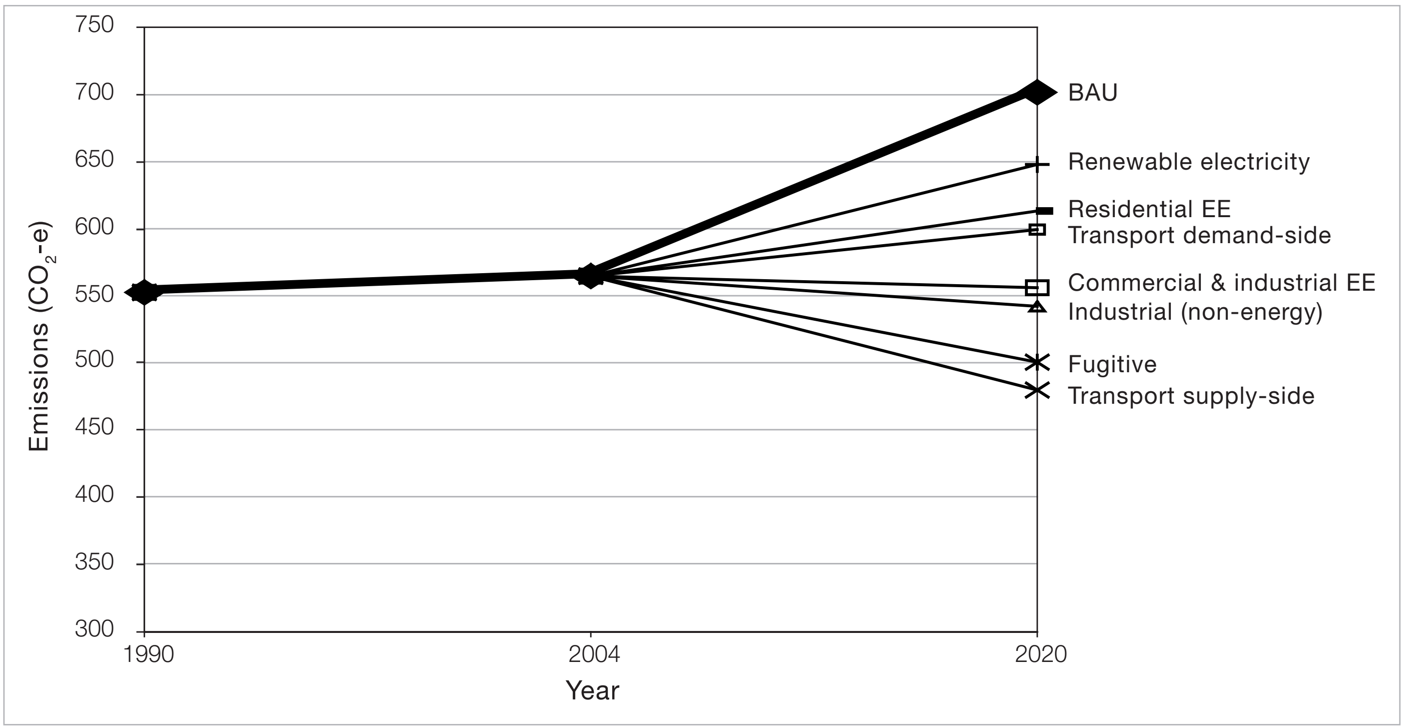
Thus this report proposes a measure to reduce business and professional immigration by 50 per cent, without reducing refugee and humanitarian immigration. See Appendix A for details on assumptions and calculations.

4. Results

4.1 Scenario 1 results

The measures used in Scenario 1 succeed in reducing projected 2020 emissions by 222 Mt, to 480 Mt per annum. This is a 31.5 per cent reduction from the AGO's BAU "with measures" projection of 702 Mt per annum for 2020. However, it falls far short of the reductions needed to meet the 386 Mt per annum goal of this study, the level needed to reduce annual emissions 30 per cent below the 1990 level of 552 Mt.

Figure 1: Scenario 1 wedges of greenhouse gas reductions, compared with AGO's BAU "with measures" projections of emissions growth



Note: EE denotes energy efficiency.

Figure 1 illustrates the wedges of Scenario 1 emissions reductions measures: renewable electricity with cogeneration (a reduction of 54 Mt CO_2-e from projected 2020 levels), residential energy efficiency (36 Mt), demand- and supply-side transport (34 Mt), commercial and industrial energy efficiency and solar heat (44 Mt), industrial process (non-energy; 14 Mt) and fugitive emissions (40 Mt).

For a detailed breakdown of Scenario 1 emissions savings by measure, see Table 4. For reference purposes, Table 4 also compares many of the larger emissions savings to those that would result from shutting down specific brown or black coal power stations.

Table 4: Annual greenhouse gas emissions reductions from measures for Scenario 1

Action	Annual emissions reduction from AGO's 2020 level (Mt CO_2-e)	Comments
A. Demand-side		
Residential energy: subtotal	***36***	
Residential hot water: Water-efficient shower-heads and aerators, 100 per cent of houses with solar, gas or heat pump hot water supply.	16.6	Saves electricity equivalent to large brown coal station (e.g. Yallourn, 1,480 MW). Gas consumption increases slightly.
Residential space heating and cooling: Strict mandatory energy performance standards for new homes, plus solar space heating for half of all homes, both new and old.	7.7	Just compensates for projected demand growth in these energy services from 2004.
Residential lighting: Improve efficiency by 75 per cent by phasing out incandescent bulbs.	4.6	Lighting emissions reduced slightly from 1999 levels of 5 Mt.
Residential appliances: 20 per cent improvement in efficiency.	7.1	Just compensates for projected demand growth from 1999
Commercial & industrial energy efficiency & solar heat: subtotal	***44***	
Commercial energy efficiency: Mainly lighting, and heating, ventilation and air conditioning.	14	
Industrial process heating: Replace low temperature (mostly gas) heating with solar thermal.	11	
Industrial energy efficiency: Measures in addition to cogeneration and solar thermal.	19	
Transport demand reduction: subtotal	***12.8***	
Passenger transport: Expand urban public transport and facilities for cycling and walking	7.5	Reduces 2020 demand for car travel to 2004 demand levels.
Freight transport: Higher fuel prices and road damage recovery.	5.3	
B. Supply side		
Renewable electricity with cogeneration: subtotal	***53.8***	
Wind power grows to 21.3 TWh, equivalent to 10 per cent of 2004 electricity generation. Installed capacity about 8 GW.	17.0	Replaces the equivalent of Hazelwood power station (1,600 MW, brown coal).
Bioelectricity grows to 17 TWh, equivalent to 8 per cent of 2004 electricity generation. Installed capacity about 2.3 GW.	15.3	More than replaces Bayswater power station (2,640 MW, black coal).
Solar thermal electricity grows to 5.3 TWh or 2.5 per cent of 2004 electricity generation in 2020.	5.3	Replaces Wallerawang C power station (1,000 MW, black coal).
Solar PV grows to 5.3 TWh or 2.5 per cent of 2004 electricity generation in 2020.	3.7	Compensates for additional gas used in balancing wind farm output and more.
Geothermal (hot fractured rock) grows to 7.5 TWh.	5	Replaces another 1,000 MW black coal power station or a smaller brown coal station.
Hydroelectricity	0	
Additional industrial and commercial cogeneration with gas: Substitutes for 5 per cent of electricity (all coal-fired) in 2020.	2.4 (electricity) + 5.1 (emissions-free heat) = 7.5	Equivalent to emissions from Mt Piper power station (1,320 MW, black coal).

Action	Annual emissions reduction from AGO's 2020 level (Mt CO_2-e)	Comments
Transport supply: subtotal	**21**	
Plug-in hybrid cars	12.8	Reduces emissions to 7.7 Mt below 2004 level.
Electric vans for all urban deliveries	4.5	Reduces 2020 emissions to 12 Mt, but does not compensate for increased demand; 2004 emissions were 11 Mt.
Diesel-electric hybrid for 30 per cent of trucks, diesohol E20 for 30 per cent of trucks and pure biodiesel for 10 per cent of trucks.	3.6	
Industrial process (non-energy): subtotal	**14**	
C. Fugitive emissions		
Stop almost all emissions, except those from open-cut coal mines.	**40**	Equivalent to total emissions from several brown coal power stations: Loy Yang A & B, Northern, Angelsea, Morwell and more. However, cutting fugitive emissions would not enable these power stations to be closed.
TOTAL SCENARIO 1	**222**	Rounded up from 221.6

4.2 Scenario 2 results

Scenario 2 starts from the same emissions reduction measures as Scenario 1 and adds further measures unique to Scenario 2 to address drivers of emissions growth. This full complement of measures reduces annual GHG emissions by 330 Mt, from BAU 2020 levels of 702 Mt (27 per cent above 1990 levels) to 372 Mt (33 per cent below 1990 levels). Thus the target of reducing emissions 30 per cent by 2020, relative to 1990 levels, is achieved and even exceeded.

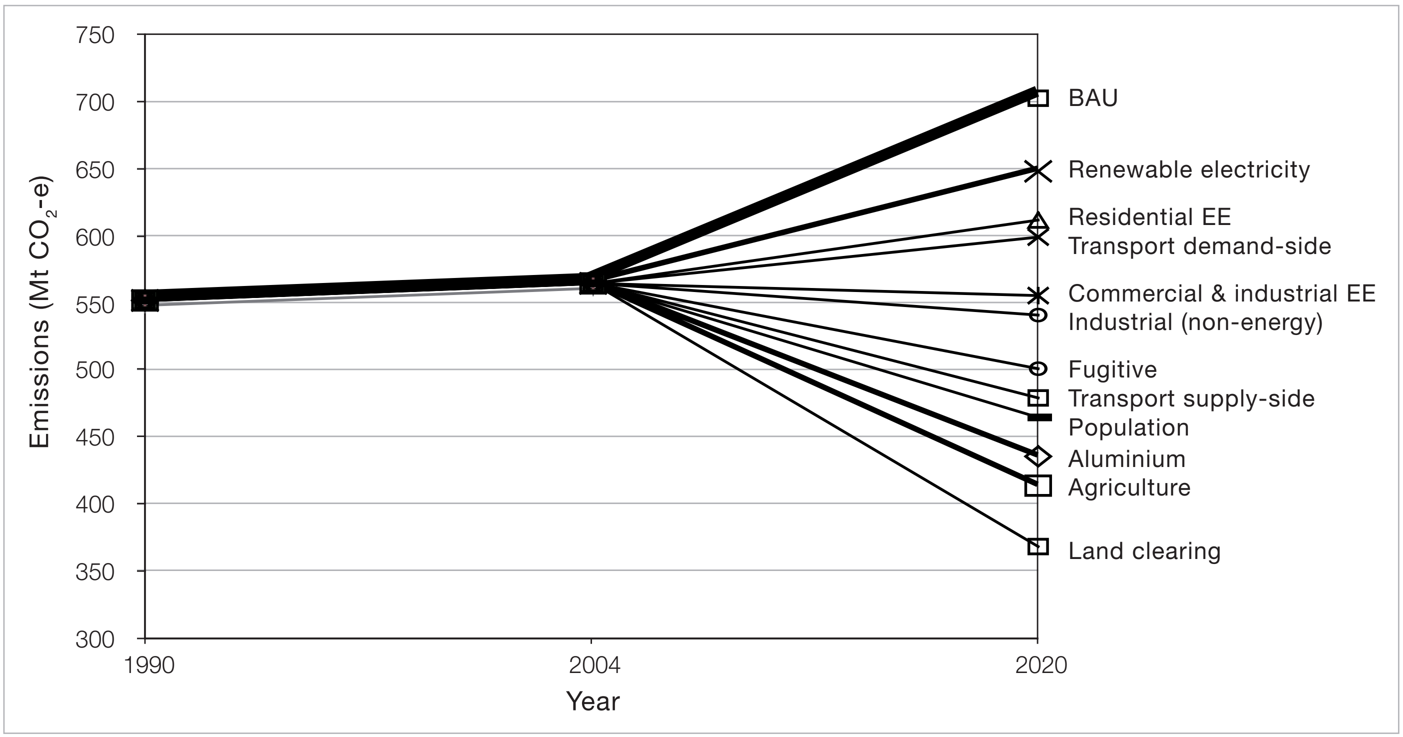
Figure 2 illustrates all the wedges of Scenario 2 emissions reductions. The additional reductions in 2020 over Scenario 1 are obtained from:

- aluminium smelting measures (28 Mt);
- agriculture measures (23 Mt);
- land clearing measures (45 Mt);
- population measures (12 Mt).

Subtotal: 108 Mt.

Including the Scenario 1 reductions of 222 Mt gives the total reduction of 330 Mt. Hence emissions in 2020 in Scenario 2 become (702 – 330) Mt = 372 Mt per annum, an outcome which is significantly below this report's target of 386 Mt.

Figure 2: Scenario 2 wedges of greenhouse gas reductions, compared with AGO's BAU "with measures" projections of emissions growth



Note: EE denotes energy efficiency.

Table 5: Annual greenhouse gas emissions reductions from measures in Scenario 2 but not in Scenario 1

Action	Annual emissions reduction from AGO's 2020 level (Mt CO2-e)	Comments
A. Demand side		
Population: Reduce population growth by halving professional and business immigration, without changing refugee and humanitarian immigration.	12	
Aluminium: Remove or offset all energy-related emissions from aluminium smelting.	28	Eliminates emissions from 13 per cent of Australia's electricity generation (mostly coal-fired).
Agriculture: Assume continuing drought, resulting from climate change, limits agricultural emissions to 2004 level of 93 Mt, a reduction of 8 Mt from the AGO projection. In addition, reduce beef production by 20 per cent for a 15 Mt reduction.	8 (drought-related limits) + 15 (lower beef production) = 23	
Land clearing: Stop land clearing and deforestation.	45	
TOTAL ADDITIONAL REDUCTIONS, SCENARIO 2	**108**	

Note: Scenario 2 also encompasses the measures detailed above in Scenario 1.

5. Discussion

5.1 General discussion

The outcome of Scenario 1 illustrates the challenge of reducing GHG emissions in the face of runaway BAU growth projections. Scenario 1 succeeded in reducing emissions in 2020 by 221 Mt, from the AGO's BAU "with measures" projection of 702 Mt, to 481 Mt. However, this falls short of the target of 386 Mt per annum.

Additional measures unique to Scenario 2, which tackle some drivers of emissions growth, were needed to reduce emissions to the level sought. Together, all proposed measures are estimated to yield annual emissions reductions of 330 Mt by 2020, to 372 Mt per annum, which is 33 per cent below 1990 levels.

Although most Scenario 1 measures are fairly non-controversial, some of those unique to Scenario 2 are politically challenging. However, these measures were chosen to be equitable and compatible with Australian society's well-being. These issues are discussed further below.

For Scenario 2 (which combines Scenario 1 and additional Scenario 2 measures), the biggest wedges of reduction were measures for: renewable electricity with cogeneration for a reduction of 54 Mt CO_2-e from projected 2020 levels, land clearing (45 Mt), commercial and industrial energy efficiency including industrial solar preheating (44 Mt), fugitive emissions (40 Mt), residential energy (36 Mt), and aluminium smelting (28 Mt).

Compared to the AGO's BAU "with measures" scenario, the proposed energy-related measures are responsible for a reduction of 208 Mt (Scenario 1 emissions minus 14 Mt of industrial non-energy emissions), while non-energy measures (agriculture, population, land clearing, non-energy industrial process) yield another 122 Mt of emissions reductions.

5.2 Specific issues

In Appendix A it is estimated that energy-related greenhouse gas emissions from **aluminium smelting** were about 28 Mt in 2004. Scenario 2 of this report considers that these emissions must be either completely removed or offset with renewable sources of electricity. One possible response for the aluminium industry would be to move off-shore. This is unlikely, considering the capital sunk in existing plant and the huge subsidies that the industry receives on electricity rates (Turton, 2002). However, if the industry decided to move, the outcome would almost certainly lower its global GHG emissions, given the carbon intensity of Australian aluminium reduction. (Overseas, most aluminium smelting uses hydro-electricity, while in Australia most aluminium smelting uses coal power.)

Note that this measure refers only to emissions from smelting, not to other aspects of aluminium production.

With regard to **population policy**, this report's proposal to reduce growth by halving professional and business immigration, without affecting refugee and humanitarian immigration, yielded a moderate wedge of annual GHG reduction, at 12 Mt. Immigrants tend to adopt Australia's energy-intensive lifestyle and hence increase their emissions once resident here. This is the rationale behind limiting business and professional immigration, while maintaining or even increasing the smaller refugee and humanitarian component.

The issue of population control is contentious, yet Australia and the wider world now face very real limits on the atmosphere's ability to absorb more greenhouse pollution, as well as scarcity of water and other resources. The need for a national population policy was discussed at a high-profile conference in Canberra in March 2007, which focussed on water, population and Australia's urban future. At the conference, world climate change authority Dr. Graeme Pearman noted:

> Indeed, the issue of population is at hand. Many of the attempts to consider what might be sustainable activities in parts of the country, attempts that are exemplary in their efforts, still exclude population. It is impossible to raise what is a difficult subject in current political and social circumstances. The question, 'Can we actually cope with the population growth and development that is occurring?', is largely put to one side. It simply needs to be on the agenda, and it needs to be more actively part of the considerations.

Thus we include this measure to provide a moderate reduction in emissions by 2020, and to draw a line under the importance this issue will have in limiting greenhouse pollution in the medium to long term.

Proposed measures to reduce **agricultural emissions** yield a moderate emissions reduction of 23 Mt per annum at 2020. The first measure is actually a default position in that we assume that continuing drought, resulting from climate change, will limit agricultural emissions to the 2004 level of 93 Mt, an 8 Mt reduction from the AGO BAU "with measures" projection. This position is supported by evidence such as CSIRO's findings that a 1˚C temperature increase or less would result in a 13 per cent reduction in Australian livestock carrying capacity in native pasture systems (Preston and Jones, 2006) and ABARE's forecasts that the 2006–07 drought will reduce agricultural production volume by 11.7 per cent for that period, compared to 2005–06 production levels.

The second agriculture measure, a 20 per cent reduction in beef production from 1990 levels for a 15 Mt emissions reduction, is more politically challenging. Beef production is chosen in this measure because it is responsible for the biggest share of livestock-related methane emissions. This measure could be accomplished by shifting to kangaroo meat and/or lower-meat diets.

Putting an end to **land clearing and deforestation** results in the second-largest wedge of annual emissions reduction: 45 Mt. This highlights the importance of the role of bushlands and forests as carbon "sinks" which absorb the greenhouse gas carbon dioxide.

Tackling the problem of **fugitive emissions** also provides a large wedge of annual emissions reductions: 40 Mt. It must be noted that the AGO's BAU "with measures" scenario forecasts an implausibly high emissions growth of 79 per cent for the period 2004–2020, considering growth from the previous 14 years (1990-2004) was a mere 3 per cent. There appears to be no rationale for an escalation in emissions of this extent. Nonetheless, proposed measures to ban flaring and venting of gas and oil field emissions, plus strict limits on emissions from existing gas and oil fields, gas pipelines and underground coal mines, could reduce these emissions by 75 per cent. The proposed measures to reduce fugitive emissions would increase the price of oil, gas and (slightly) coal.

6. Conclusion

The evidence that human-induced global climate change is accelerating establishes the need for strong emissions reduction targets for 2020, 2030 and 2050. Achieving an interim GHG reduction target of 30 per cent by 2020 is vital to put Australia on track to reduce GHG emissions by at least 80 per cent by 2050, widely accepted as the minimum reduction required by a developed country to avoid dangerous climate change.

Undermining the development of such strong greenhouse gas reduction scenarios are the business-as-usual (BAU) scenarios published by government organisations, such as ABARE and AGO, and industries with a vested interest in activities that result in the production of greenhouse gases. These scenarios project high growth in emissions and sometimes present them as a law of (human) nature instead of a danger that must be avoided.

In the face of AGO's projected BAU emissions growth to 702 Mt per annum in 2020, the present study achieved the major part of the necessary reductions through technology switching in the energy/transport sector alone (Scenario 1). To meet the target of 30 per cent cuts by 2020, Scenario 2 went further to address some of the driving forces behind BAU emissions growth, including Australia's principal energy-intensive industry (aluminium smelting), land clearing, diet and population growth.

The GHG abatement measures proposed in Scenario 2 of this study reduced annual CO_2-e emissions to 33 per cent below 1990 levels (to 372 Mt per annum) by 2020. In total, the measures proposed in this report were estimated to achieve a reduction of 330 Mt per annum from the BAU projection for 2020. This emission reduction is equivalent to the annual emissions produced by about 55 1,000-MW black coal-fired power stations.[13]

The measures proposed in this report utilise energy efficiency, renewable energy and natural gas cogeneration technologies, and the capture of fugitive emissions from fossil fuels. These measures are safe, available now and require no major technological breakthroughs. We also included promising technologies and measures which, although only capable of minor contributions by 2020, could produce substantial additional reductions beyond 2020. These include solar electricity, geothermal power, improvements in urban public transport, and plug-in hybrid and all-electric vehicles.

The largest wedge of reductions was obtained through 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) would dwarf even the contribution from the above measure for renewable electricity with cogeneration.

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

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 new generation of nuclear power stations which will ultimately become significant CO_2 emitters as the limited reserves of high-grade uranium ore are used up.

The present 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 current policy neglect of energy efficiency, solar hot water, wind power, bioenergy, cogeneration, solar electricity, public transport and electric vehicles must be reversed. With strong support for industry development, market development and technological development, these clean energy technologies could make an even greater contribution by 2020, perhaps negating the need for some of the more politically challenging non-energy measures cited in this report.

13 Since many of the emission reduction measures relate to transport and non-energy uses (e.g. land clearing), they do not equate to actually enabling Australia to shut down that many coal-fired power stations, which is much more than the actual number of such plants.

The necessary policies must involve setting GHG emissions reduction targets[14], carbon pricing, mandatory renewable energy targets (MRETs), regulations and standards for energy efficiency, institutional changes, education and R&D funding (Diesendorf, 2007a). Funding for the transition can be obtained from carbon pricing, MRETs, the application of mass-distance charges to road freight, and the removal of existing government subsidies to the production and use of fossil fuels (Riedy and Diesendorf, 2003; Riedy, 2007).

So far no Australian federal or state government has committed to a GHG reduction target for 2020 or sooner. The dearth of interim targets may be explained by both major Australian political parties' hopes that domestic emissions can in future be addressed by unproven technology for capture and burial of emissions from coal power plants, which constitute Australia's largest single source of greenhouse pollution. Yet even the World Coal Institute concedes that only nine coal power plants with CCS plants are likely to be operating worldwide by 2020**.** An interdisciplinary team of experts from the Massachusetts Institute of Technology envisages that coal with CCS may take off on a global scale around 2025 and may overtake the contribution of renewable energy around 2045 (Ansolabehere et al., 2007). Clearly CCS is not a possible near-term solution.

Without meaningful targets for the near future and strong action commencing now, long-term targets will be unachievable and Australian energy emissions will continue to escalate. Short-term targets are particularly important now that evidence is being published that global warming is accelerating under the action of several amplification processes. As in the case of water management, policy implementation for deep and rapid cuts in GHG emissions will require a concerted effort by government, industry and the community at large.

14 Not merely reductions in the projected BAU rate of growth in emissions, but absolute reductions in megatonnes compared with emissions observed in a past year such as 1990.

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Appendix A: Details of some calculations

A.1 Population growth & emissions

The following is a rough estimate of the impact on 2020 greenhouse gas emissions of changing the immigration rate. The calculation has a number of assumptions (e.g. that population and emissions grow exponentially).

Population component: In 2005–06, permanent immigration into Australia was 180,000, comprising the following categories:

- Family 46,000
- Skill (business and professional) 91,500,
- Humanitarian 17,000,
- Non-migration (mostly New Zealanders) 25,000 and Special 310 (DIMA 2006).

Permanent departure was 68,000. Therefore, net permanent addition from migration was 112,000, or about 0.54% per annum.

Australia's overall population growth rate is 0.95% per annum.

By halving the Skill (business and professional) category of immigration, population growth would be reduced to (0.95 – 0.22)% = 0.73%. Then total population growth 2008–2020 would be about 10 per cent. Thus the projected population in 2020 is reduced from 23.3M to 22.8M; Δ = 0.5M (reduction).

Emissions component: The calculation now focuses on emissions from the Energy category (excluding fugitive emissions), which, to a good approximation, are directly proportional to Australia's population. The AGO's projected growth in emissions from stationary energy and transport over 2004–2020 is about 29.3% (Table 1), corresponding to an annual growth rate of 1.62%. Assume that emissions are proportional to population (as well as to "affluence" and "technology"). Then rate of emissions growth from Energy (excluding fugitive emissions) after cutting Skill migration, equals (1.62 – 0.22)% p.a. = 1.4% p.a., giving a growth factor over 2004–2020 of 24.9% instead of AGO's BAU "with measures" growth rate of 29.3%.

BAU emissions in 2020 from Energy (excluding fugitive), with reduced Skill immigration, become 444.6 Mt instead of AGO's 460.5 Mt, Δ = 16 Mt (reduction).

However, about one-quarter of these emissions would be for export from manufacturing and mining; these emissions are largely unaffected by population, and so the emissions savings are deemed to be reduced to 12 Mt.

Conversely, parts of emissions from Agriculture, Fugitive, Land Use and Waste can be attributed to domestic use and hence Australia's population. However, this report has already pointed out that AGO's projected emissions from these categories could be slashed by other actions. Provided these suggestions are implemented, the additional benefits of immigration reduction on emissions from these categories will be small and are therefore ignored here.

A.2 Fugitive emissions

Scenario 1 rejects AGO's BAU assumption that fugitive emissions will accelerate from a growth of 3% over 1990–2004 to 79% over 2004–20. Instead we assume a reduction to half of the 2004 level by 2020. Reduction in AGO's BAU level = (15.5 + 24.4) Mt = 40 Mt.

A.3 Residential, demand-side

Residential hot water

Baseline residential stationary energy emissions in 1999 equals 63 Mt. Assuming a 22% BAU growth from 1999, this would become 77 Mt in 2020.

Since hot water is responsible for 27% of residential energy-related (stationary) emissions, BAU residential hot water emissions in 2020 = 21 Mt.

Assume universal use of water efficient shower heads and tap aerators reduces this by 30%, so residential hot water emissions → 14.6 Mt.

Then assume *all* hot water systems in 2020 are solar (gas and electric boosted) and electric heat pump with average emission reduction 70% reduces emissions to 4.4 Mt (compared with actual emissions of about 17.5 Mt in 2004). Total emission reduction from BAU = (21 – 4.4) Mt = 16.6 Mt.

Residential appliances

2020 emissions calculation: 42% of residential stationary energy emissions equals 29 Mt in 1999. Assuming a 22% BAU growth from 1999, these would become 35.5 Mt BAU in 2020.

Emissions reduction calculation: Assuming 20% improvement in energy efficiency reducing emissions to 28.4 Mt, slightly below 1999 level. Thus efficient energy use reduces BAU emissions by 7.1 Mt, but only just compensates for projected demand growth.

Residential space heating & cooling

2020 homes calculation: At a construction rate of 1.75% p.a. of homes, 32% of the 2004 number of homes will be new in 16 years. That is, assuming net growth in home numbers is 20% to 2020, 32%/1.2 = 26.7% of number of 2020 homes will be new. Assume new homes demand half the energy for space heating and cooling of old homes. In addition, assume 50% of space heating of all homes is supplied by solar.

2020 emissions calculation: Residential space heating and cooling is currently 18% of residential stationary energy emissions = 14 Mt in 2020.

Emissions reduction calculation: Emissions in 2020 = 14 x 0.267/4 Mt from new homes + 14 x 0.77/2 Mt from old homes = (0.9 + 5.4) Mt = 6.3 Mt, a reduction of 7.7 Mt from BAU in 2020 or, compared with 11.3 Mt in 1999, a reduction of 5 Mt.

Residential lighting

Lighting is responsible for 8% of residential stationary energy emissions. 5.1 Mt per year in 1991 becomes 6.2 Mt in 2020. Assuming a 75% reduction, gives emissions in 2020 = 1.6 Mt, a reduction from BAU of 4.6 Mt. Compare with 5 Mt in 1999.

A.4 Industrial

Aluminium smelting

Aluminium smelting used 15 per cent of Australia's electricity production in 1999 or about 13 per cent in 2004. Corresponding energy-related emissions in 2004 were 0.13 x 213 TWh x 0.915 Mt/TWh = 25.3 Mt. The latter estimate assumes that the average greenhouse intensity of electricity generation from aluminium is the same as the average greenhouse intensity of all electricity generation in Australia. Since the vast majority of aluminium is smelted in Australia from coal power in Victoria, New South Wales and Queensland, the 25.3 Mt is likely to be an underestimate. According to Wilkenfeld's end-use allocation, emissions in 1999 were 31.5 Mt from electricity and, taking into account emissions unrelated to energy, total emissions were 52.6 Mt CO_2-e. The departure of this industry or its conversion to low-carbon fuel and electricity could reduce Australia's *total* greenhouse gas emissions by nearly 10%. This report only considers removal of energy-related emissions from aluminium smelting and ignores emissions from alumina production. It takes an intermediate level of emissions between the above two estimates of 25.3 Mt and 31.5 Mt, namely 28 Mt. Further analysis is needed of all greenhouse gas emissions from the alumina/aluminium industry in Australia.

Industry (energy emissions excluding aluminium)

Energy efficiency: From Wilkenfeld: excluding aluminium, industry component of (116 – 52.5) Mt = 63.5 Mt from stationary energy in 1999.

Growth ratios 2000–2040 from Clean Energy Future report are: non-ferrous metals (mainly aluminium) 1.8, iron & steel 1.4, cement 2.2, mining (non-energy) 2.2, wood and paper 1.4, ag/forestry/fishing 2.3. Thus, excluding aluminium, assume average BAU demand growth of the remaining industrial energy emissions 1999–2020 is 50% to 95 Mt.

Assume that energy efficiency cuts about 20% on average by 2020, reducing emissions from 95 Mt to 76 Mt, a saving of 19 Mt.

Low-temperature heat from solar thermal: From Wilkenfeld fig. 8.1: Fuel energy use from Manufacturing (excluding cogeneration and mobile contributions) ~ 36 Mt in 1999 which we project to 2020 to become 54 Mt. Assume 20% could be supplied by solar thermal. This is 11 Mt in 2020. Assume that this is a separate item from emissions savings from heat obtained from cogeneration and from energy efficiency.

Industrial process (non-energy)

This measure rejects the AGO's BAU assumption that the growth in non-energy industrial processes will accelerate from 20% over 1990-2004 to 67% over 2004–20. For our baseline growth, we assume that the 20% growth is maintained to 2020, thus saving (50 – 36) Mt = 14 Mt of CO_2-e emissions.

Commercial energy efficiency

According to Wilkenfeld (2002), the stationary component (comprising the vast majority) of commercial emissions grew by 45% from 1990 to 1999, when it reached 46.5 Mt. Assuming a BAU growth of 50% over 2000–20 gives a projected level of 70 Mt in 2020. However, this could be an underestimate because the growth rate actually accelerated over the period 1995–99.

About half these emissions result from heating, ventilation and air conditioning (HVAC) and about one-quarter from lighting. Assuming that this is the same proportion for BAU in 2020 and that lighting efficiency could be improved by 40% gives a saving of 7 Mt. HVAC saving depends to a large degree upon building design and turnover. Since the latter is much smaller than for residential buildings, we assume conservatively that 20% savings in HVAC (7 Mt) could be achieved by 2020, followed by much greater savings in the longer term. Thus total commercial energy efficiency savings for 2020 become 14 Mt.

A.5 Electricity

Assume electricity supply in 2020 for these users, after reducing population growth according to the calculation for population above, is 20% above 2004 level of 213 TWh p.a., in the absence of efficient energy use. Thus electricity consumption in 2020 would be 256 TWh p.a. With the current energy generation mix (mainly coal), this would correspond to 234 Mt CO_2-e p.a. Then efficient energy use in residential sector reduces emissions to 192 Mt.

Wind

10% of 2004 electricity generation by 2020 = 21.3 TWh/yr.

Assume conservatively 80% reduction in emissions compared with coal (allows for brown and black coal; balancing with open-cycle gas turbines; and some substitution for gas).

Electricity generation was 213 TWh in 2004. Wind equivalent to 10% of 2004 = 21.3 TWh. If capacity factor = 0.3, this corresponds to installed capacity of 8.1 GW. Assume average coal greenhouse intensity is 1 Mt CO_2-e/TWh. So wind substitutes for 0.8 Mt CO_2-e/TWh (allowing for increased use of peaking gas; brown & black coal) → reduction in emissions of 17 Mt.

Bioelectricity

8% of 2004 electricity generation by 2020 = 17 TWh. f = 0.85. Capacity = 2.3 GW.

Assume 90% reduction in emissions compared with coal (allows for processing biomass and some transport). Substitutes for 0.9 Mt CO_2-e/TWh = 15.3 Mt.

Solar electricity

Solar thermal electricity with thermal storage (baseload)

2.5% of 2004 electricity generation by 2020 = 5.3 TWh.

Assume 100% reduction in coal emissions, saving 1 Mt/TWh → 5.3 Mt, replacing Wallerawang C (1000 MW, black coal station, NSW).

Solar PV (intermediate load)

2.5% of 2004 electricity by 2020 = 5.3 TWh.

Substitutes a mix of combined-cycle gas and old coal, replacing 0.7 Mt/TWh = 3.7 Mt

Total emissions reduction from solar electricity: 9 Mt

Hydroelectricity

Assumed no new large hydroelectric dams; any increase in hydroelectric capacity from new small dams and improved efficiency of existing hydro power stations offset by reduced rainfall into dams. Hence there are no additional greenhouse gas reductions from hydroelectricity.

Geothermal (hot rock)

Assume conservatively that it replaces one 1000 MW black coal station, emissions saving of 5 Mt, by 2020.

Cogeneration with gas

Assume additional cogeneration substitutes for 5% of electricity.

Electricity component of cogeneration (not combined cycle) provides 25% reduction in CO_2 compared with black coal. Saving in 2020: 192 Mt x 0.05 /4 = 2.4 Mt.

However, heat saving is 100% reduction in emissions for heat consumed.

Heat generated from 5% of electricity: 9.6 TWh electrical = 27.4 TWh thermal

= (27 x 3.6) PJ = 99 PJ. Assume conservatively that all this heat would have been produced by burning natural gas with emissions of 52 kt CO_2/PJ. Then emissions saved = 5.1 Mt.

Total emissions savings from cogeneration: 7.5 Mt.

Total reduction in emissions from electricity generation = 53 Mt = 22% of projected BAU 2020 electricity emissions of 241 Mt. Greenhouse intensity of electricity generation is reduced from 0.915 Mt CO_2-e/TWh in 2004 to (241 – 53)/256 Mt CO_2-e/TWh = 0.73 Mt CO_2-e/TWh in 2020.

A.6 Transport

Plug-in hybrid cars

2004 passenger vehicle emissions: 41.7 Mt

Growth factor for passenger vehicles: 1.2% p.a. from 1990 to 2004; assume this continues to 2020 in absence of demand reduction measures = growth factor 1.18. So 2020 emissions become 49.6 Mt. Less 6% for demand reduction → 46.6 Mt.

Average fuel (petrol or diesel) reduction per vehicle: 50%.

Coverage: all urban-based motor cars, assumed to be 85% of Australia's motor cars.

Therefore, emission reduction = 19.8 Mt and reduced 2020 emissions are 26.8 Mt.

Emission reduction from oil consumption is partially offset by emissions from increased electricity generation.

Based on US EIA data: average electricity demand per year from plug-in hybrid vehicle (20 miles or 32 km pure electric per charge) is about 1.8 MWh/yr/vehicle.

Number of registered cars in Australia 2002-03: 10.4 million (M) → (12.7 x 0.94) M = 12 M in 2020.

So their total electricity consumption would be 21.6 TWh/yr in 2020 or about 10% of Australia's electricity generation in 2003-04 or 2020.

If 2020 grid has greenhouse intensity 0.695 Mt CO_2/TWh, increase in annual emissions = (21.6 x 0.695) Mt = 15.0 Mt.

Net reduction in 2020 emissions = (26.8 - 15.0) Mt = 12.8 Mt, increasing post-2020 as grid becomes “greener”.

All-electric vans

Australia’s 2004 emissions: 11 Mt from LCVs.

Growth factor for vans: 2.7% p.a. from 1990 to 2004; assume this continues to 2020 in absence of demand reduction measures. Total growth factor 1.53, increasing emissions to 16.8 Mt.

Number of registered vans in 2002-03 = 1.9M → 2.85 M in 2020. Using petrol and diesel, total emissions would increase to 16.8 Mt. For significant reductions, need pure electric for all vans. Saving 16.8 Mt p.a. in 2020.

Increase in electricity demand: 0.5 kWh/mile (EIA, Ford ecostart) = 0.31 kWh/km.

Over 20,000 km/year, annual consumption = 6.25 MWh x 2.85 M vans → 18 TWh → (18 x 0.695) Mt emissions = 12.5 Mt emissions.

Net emission reduction for vans = (16.8 – 12.5) Mt = 4.5 Mt, increasing post-2020 as grid becomes “greener”.

Freight trucks

Truck numbers: In Australia during 2003-04 there were 409,000 trucks which covered 13.9 billion vehicle-km.

Emissions from ‘Trucks & buses’ in 2004: 15.1 Mt, an increase of 35% from 1990.

Assumed that demand management stops increase in use of freight trucks by 2020.

Assumed mix of technologies:

- 10% of trucks fuelled from 100% biodiesel with 90% reduction in emissions (reduction 1.36 Mt);
- 30% of trucks fuelled with diesohol E20 (20% ethanol + 80% diesel) reducing emissions by 0.9 Mt;
- 30% switch to hybrid diesel-electric with 30% reduction in emissions (reduction 1.36 Mt).

Total reduction: 3.6 Mt.